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for all
SCIENCE AND
MATHEMATICS
TEACHERS**



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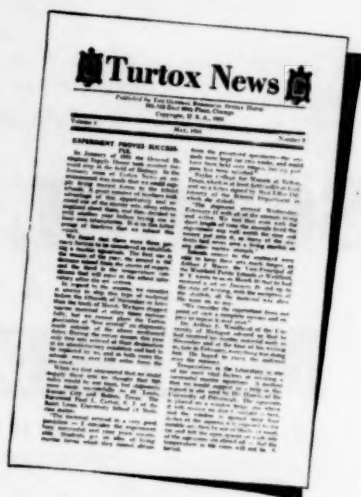
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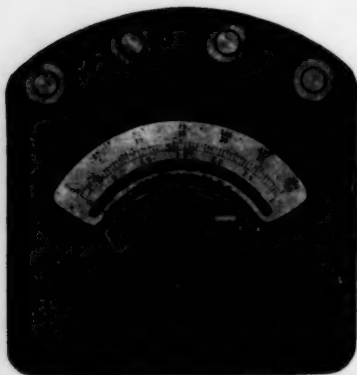
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SCHOOL SCIENCE AND MATHEMATICS

VOL. XXXVII

FEBRUARY, 1937

WHOLE NO. 319

THE VISUAL ROUTE TO EDUCATION*

BY ARTHUR O. BAKER

John Marshall High School, Cleveland, Ohio

With the development of the little red school house on the hill, the teacher in charge paved the way for many of the methods in education which are still in use. It was assumed that he was a highly talented, versatile, individual capable of teaching the entire curriculum—English, mathematics, history, agriculture and economics. Consequently, with little or no time for preparation this teacher found that he could, if skillful, conduct *question and answer discussions* most easily and still maintain reasonable discipline and interest.

Later educators learned to departmentalize and to train teachers to teach certain subjects. However, the *question, answer, discussion* method is still in wide usage.

Then came the dawn of the motion picture upon the educational horizon and now comes the addition of the human voice to visual instruction.

These are wonderful educational tools capable of meeting in fifteen minutes the same educational objectives *in certain instances* that frequently required days of patient instruction or the spending of many periods in the laboratory. For example the two Chicago-Erpi sound films —“Sound Waves and their Sources” and “Fundamentals of Acoustics”—are powerful allies of instruction in the principles of sound.

* Prepared by Arthur O. Baker, Head of the Science Department, John Marshall High School, Cleveland, Ohio. This school was selected for some of the experimental work in visual education. The techniques developed have been filmed. This motion picture will be loaned for educational purposes.

The big problem in visual education today is to teach teachers to use such materials effectively and intelligently. Many teachers are making some or all of the following mistakes:

1. Adhering strictly to the *question, answer, discussion* method.
2. Not using visual materials at all or insufficiently.
3. Not correlating the use of films definitely with assignments.

For example the class may be studying "Dairying and Milk Products" and the film shown to them may be on "Tuberculosis." Such indirect correlations are not very valuable.

4. The showing of pictures for mere entertainment.
5. Failure to prepare assignments and tests based definitely on visual materials when used.
6. Emphasizing technical processes and the development of scientific skills in the laboratory. With the motion picture as an ally, work in the laboratory should become less technical and more *exploratory*.

THE JONES ROTARY SYSTEM OF INSTRUCTION

This is an experimental procedure being used in history and science in several schools in Cleveland with a view to developing the techniques involved in the VISUAL ROUTE TO EDUCATION. This system has been so named because of the experimental procedures developed by Dr. R. G. Jones, former Superintendent of Schools, Cleveland and because of the fact that teacher activity *rotates* with pupil activity.

Criticisms of the Regular Mode of Classroom Instruction

1. With large class enrollments averaging thirty-five or more pupils, the class recitation period resolves itself into a lecture upon the part of the teacher or a discussion period in which a small per cent of the class participates, because of the large size of the groups.

2. If the lecture method is pursued, the teacher delivers twenty to thirty lectures per week, depending upon the number of class periods to which he is assigned; or if he proceeds by discussion he conducts a similar number of discussions. If a teacher has six classes per day, he probably conducts good lectures and discussions during the first two classes of the morning but these

forms of teaching become "pumping and drill exercises" in the third, fourth, fifth, and sixth period classes in the afternoon.

3. Lectures and discussions when thus conducted are exhaustive in energy and inefficient in outcome. Lectures are valuable when they are *well prepared*, involve demonstrations, and are delivered at a maximum of efficiency on the part of the instructor. Discussions are valuable when held in groups sufficiently small in size that all members of a particular group participate.

New Classroom Instruction Goals

1. *Visual demonstrations* delivered to large groups at a maximum of efficiency on the part of the instructor.

2. The use in large groups of lantern slides, silent, and sound films, exhibit and demonstration material and the *microphone*. Thus all pupils *see* and *hear* effectively.

3. The preparation of clarified assignments, and modern tests.

4. The preparation of such correlated work sheet exercises, based upon the visual aids used, that lantern slides and films become agents of instruction demanding the attention of the student. Too frequently in the past visual aids have been used in classes in such a manner as to result in pure entertainment.

5. Discussions in groups of such a small size that all members participate.

6. The development of leaders and leadership by placing students in charge of small groups for certain activities.

7. The establishment of teacher-pupil contact.

8. The inclusion of a reasonable amount of *guided* study.

9. The securing of such individual pupil activities as the performing of experiments and projects.

How to Install the Jones Rotary System of Instruction

1. The adoption of this plan should not mean an increase in daily pupil load; nor should it mean an increase in the number of scheduled periods required per teacher per week. Let us give the classroom teacher time to really prepare his work. The teacher should spend his free periods:

- a. Preparing clarified assignments
- b. Preparing modern tests
- c. Designing lantern slides to correlate with the visual demonstrations

2. It should mean the setting up of large groups (of the already existing daily pupil load) for *visual demonstrations* and the setting up of small groups for the realization of the additional goals of classroom instruction.

3. Mechanical equipment needed:

- a. A large room in which visual aids can be used in connection with the demonstrations. This room should be equipped with a microphone and loud-speaker. The microphone enables all students to *hear effectively*.
- b. Small laboratories and conference rooms.
- c. Cellophane lantern slides to substitute for many of the diagrams and drawings used on the classroom blackboard. These enable all pupils to *see effectively*. These should be used in semi-darkness, thereby permitting note taking.
- d. Apparatus wagon with ball-bearing wheels to transfer apparatus and equipment with dispatch.
- e. An illuminated portable blackboard.
- f. Silent and sound motion picture projectors.

A PUPIL'S SCHEDULE WHO REPORTS FOR 2ND PERIOD VISUAL DEMONSTRATION AND 7TH PERIOD CONFERENCE

	1	2	3	4	5	6	7	8	9
M		Visual Demon.							
T							Guided Reading		
W		Visual Demon.							
Th							Conference*		
F		Assignment and Test							

* Conference period may be spent in several ways depending upon the judgment of the teacher:

1. Laboratory exercises
2. Discussion period for the group of 20 to 25 pupils
3. Drill exercises
4. Conference group of 25 pupils may be broken up into 5 small groups with 5 pupils in each. Group leaders may be selected by the teacher and one may be placed over each group to:

- a. Review the assignment
- b. Conduct a project or experiment
- c. Hear oral reports
- d. Conduct review drills
- e. Conduct a discussion

The teacher may confer individually at this time with pupils who are failing in their work.

Advantages of the Small Conference Group of 25 Pupils

1. The teacher is assured that in the course of a week each pupil has personally read a minimum of one period in preparing the assignment.
2. Fewer pieces of apparatus required because of the small size of the group.
3. Experiments can be performed more individually.
4. All members of the group of 5 take part in the discussion because of the small size of the group.
5. Pupils may examine the demonstration material closely which was used during the lecture periods.

Advantages of the Rotary System

1. Teaching periods cut from 30 per week to 24
2. Teacher has time to prepare his work
3. Monotony is avoided
4. VISUAL INSTRUCTION USED EFFECTIVELY

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The National Home Library Foundation today announced its plans for the distribution of a million copies of new books of special interest to educators, to be made available at 25 cents per volume. Distribution of these books, published on a non-profit basis, will begin immediately to all sections of the country. Titles have been approved by an advisory board of sixty-six of the most distinguished names in the arts and sciences, ranging from James Truslow Adams, Eugene O'Neill, Louis Untermeyer, William Allen White, to Dorothy Canfield Fisher, Professor John Livingston Lowes and Dr. Willis A. Sutton. These books are beautifully bound in cloth and printed in large, clear type on a fine grade of paper. The Foundation will extend special discounts to educators on all quantity orders.

List of titles now available:

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The Complete Poetical Works of John Keats—

Jefferson, Corporations and the Constitution—Dr. Charles A. Beard.

HOW TO TEACH PHYSICS

BY R. B. ABBOTT

*Physics Department, Purdue University**

The problem of "How To Teach Physics" is a very serious and complicated one. It is serious since physics is the foundation of all engineering and therefore should be taught well and thoroughly; it is complicated because (1) it involves the use of mathematics for the quantitative analyses of problems and theory of measurements, (2) it involves scientific methods of logical reasoning regarding new concepts and physical laws, (3) it involves a knowledge of correct methods of study and concentration so that the student can learn to work efficiently and keep up with the presentation of the subject matter, (4) it involves a knowledge of the speed with which the subject matter can be given so that normal students can comprehend and master it.

The problem of "How to Teach Physics," like any other problem in physics, is best solved by first assuming ideal conditions in order to simplify it. For example, at first one neglects friction in the laws of motion and afterwards adds it as a correction to the ideal case. So it would seem convenient to assume at first an ideal man as teacher and a class of normal students as the participants in a physics class. We can think of them as mechanized beings if we wish. In this way we get rid of the many troublesome variable quantities which bring in the physical, ethical and cultural characteristics of the teacher, and the variation of student mentality. Afterwards, we can consider these quantities and make the proper corrections to our theoretical solution.

To solve this simplified problem it is only necessary to resort to the fundamental laws of psychology relating to mental processes and formulate a set of guides to direct the action of the teacher in this hypothetical physics class. This set of guides so formulated is the answer to our theoretical problem and constitutes the "fundamental aims of a teacher." There is nothing new here, except the method of analysis and possibly the bringing together of these aims into one formulation. They can be gleaned from present texts on teaching methods.

The following attempt to get such a theoretical solution to

* Read before the Chemistry and Physics Section, Indiana State Teachers Association at Indianapolis, October 22, 1936.

our problem was made after having read textbooks and articles on teaching physics, conferring with Professors of Physics and Professors of Education, and having tried many experiments on methods of teaching physics. The principle fundamental aims of a teacher of physics may be formulated as follows:

- (1) to present an outline of the aims of the course,
- (2) to supply the subject matter by lecture, by textbook, or by both, and to induce in students a motive or incentive to study with interest,
- (3) to direct or lead students in the proper understanding and use of the subject matter,
- (4) to give students practice in applying the fundamentals to the analysis of problems and in making physical measurements, by repetition, by reproduction of selected exercises and deductions, and by doing experiments,
- (5) to measure the relative gain of the students from time to time toward the accomplishment of the aims of the course as outlined in (1).

Each of the above fundamental aims of a teacher can be amplified greatly but space will not permit, so only a few clarifying remarks will be made. Take for example the first aim, namely, to present an outline of the aims of the course. A general outline of the aims of general physics for engineering students may be stated as follows: (1) to arouse and stimulate interest in the physical world around us, and give the fundamentals of general physics covering the topics of mechanics, heat, sound, electricity and light; (2) to show the student how to use the fundamentals scientifically in analyzing both quantitatively and qualitatively physical phenomena, systems and mechanisms met with in laboratory, in factory, and in every day life.

Stated more specifically the aims are: (1) to give the student a knowledge of the fundamental laws and concepts of physics, (2) to show him how to make quantitative analyses of physical problems, (3) to show him the technique of physical measurements.

An outline of the aims of general physics for culture students may be stated in the same words excepting the substitution of the word "qualitatively" for "quantitatively and qualitatively."

Take the second and third aims, namely, to supply the subject matter by lecture, by textbook or by both, and to induce in students a motive or incentive to study.

The lecture method is used where outlines and textbooks are not available and where demonstrations are necessary and sometimes for inspirational purposes. The third and fourth aims, namely, to direct and to drill are accomplished in recitations and conferences.

The fifth aim, namely, to measure the relative gain of the students toward the accomplishment of the first aim as described above, is accomplished by means of examinations which are designed to measure the progress of students toward accomplishing this aim. Such examinations have been a subject of research in Education and are well treated in texts on the subject.

That specific aim for engineering students which needs the most emphasis is, "to teach students how to make quantitative analyses of physical problems." Since this formal mathematical method apparently is not given in any textbook, it might be well to speak of it here.

First, it is assumed that one knows the physical laws and concepts involved in the field of the problem to be analyzed.

Find by the use of these laws and concepts as many relations (equations) between the known and unknown quantities as there are unknown ones. Find the answers (unknowns) by solving these relations as simultaneous equations.

One of the ideal conditions assumed at the beginning of this problem was that of a normal person acting as an ideal teacher. That is to say, it was assumed that a normal person would react to all phenomena peculiar to teaching in an ideal manner. The following physical characteristics of a man were assumed to constitute those of a normal human being.

1. Biological (mechanical and chemical) mechanism normal.
2. Emotions balanced.
3. Passions and appetites under control.
4. Mental and nervous reactions normal and accurate.
5. Memory normal.

Besides these, it was assumed that the following cultural characteristics were added to the physical, to complete the idea of the ideal teacher.

1. A practical and theoretical knowledge of the subject taught.
2. Ability to state or explain ideas clearly in fundamental terms if necessary.

3. A normal interest in the subject and a desire for more knowledge.
4. Humility and consideration for other's views.
5. Fairness and patience.
6. An understanding of human nature.
7. A desire to be of service.
8. Consistency in practice and precept.
9. Neatness and Cleanliness in every day habits.
10. Promptness in every act.

If a teacher departs from the ideal normal man as outlined above in one or more ways many things may happen. If the teacher and class both depart from normal in a number of ways many more things may happen.

Let us take a few cases where our ideal conditions do not hold and see what corrections are necessary. For example, if we have our ideal teacher with a class of geniuses, his aims will be reduced to only one, namely, to supply the subject matter. If on the other hand, the class be composed of persons much below the average ability, all of the above aims must be carefully followed by the teacher. The actual case always falls between these extremes. The ideal teacher must govern his aims by a knowledge of the characteristics of his class.

As an example of poor teaching, suppose a teacher has students of inferior abilities and he aims only to present the material of the course by lecture, to give the aims of the course and then give examinations to test the gain of his students toward the aims undertaken. Unless the aims are very low and the tests made very easy, the results will be unsatisfactory because such students need to be guided and drilled.

Suppose a teacher did not make out any aims for his course, how could he make out a valid test for measuring purposes?

In conclusion let me say that this old problem was considered in the above mathematical form for analyses in order to take it out of the realm of guessing where possible. There is nothing new about it except its dress.

JUNIOR-HIGH-SCHOOL CONFERENCE

The 13th Annual Junior-High-School Conference is to be held on March 12-13, 1937 at New York University, Washington Square.

MAURICE S. HAMMOND, *Chairman*

THE WEATHER CLUB

BY KERMIT J. BLANK

Raub Junior High School, Allentown, Pennsylvania

The Raub Junior High School in Allentown, Pa., boasts of two unique and unusual clubs as part of its activities program. The Weather Instrument Makers and the Weather Forecasters were organized to meet the desire of pupils to pursue, to a greater degree, the study of weather. For those manually inclined the Weather Instrument Makers offers a fine outlet; for those interested in weather as a hobby, the Weather Forecasters Club serves as a training school.

ORIGIN

The significant thing about the origin of these groups is that the pupils themselves were the instigators. Their interest in that part of the General Science Course devoted to weather was so marked and their desire to learn to use weather instruments so great that two teachers decided to make this interest the basis for club activity. One teacher, a shop instructor, sponsors the group which builds the instruments while the other, a science teacher, sponsors the forecasting group.

From this point only the Weather Forecasters Club will be discussed, excepting where there is an interlinking of activities.

PRINCIPLES OF ORGANIZATION

The group was organized along lines which are most generally accepted by authorities on activities.

- (1) The club is based on definite and worthy objectives. It has set up for itself the following aims:
 - (a) "To satisfy our interest and increase our knowledge of weather."
 - (b) "To supply a daily weather report to our school and the homes represented in our school."
 - (c) "To make our Weather Bureau a source of pride to the Raub School."
- (2) The purposes and activities of the club are really those of its student members. It was by their suggestion that the various divisions of the stepping up program were prepared. They set up the qualifications and altered them as they secured new information. The activities

are entirely of their own proposal; for example, the daily weather report to each home room.

- (3) The club grew out of the curriculum as was explained in the discussion of the origin.
- (4) The club fits into the local situation very nicely. There is no weather station within thirty-six miles, which makes the members feel that they are more or less responsible for local forecasts
- (5) Membership is open to every pupil who has a passing grade in the major subjects. Pupils make a first, second, and third choice of clubs; and wherever possible they are given the club of their first choice.
- (6) There are absolutely no fees, dues or assessments. The only expense to a member is an optional one. The National Carbon Co. puts out a booklet and weather wheel for ten cents. If a member cares to have this material he can buy it, but it certainly is not required.
- (7) There is no limit on the membership. The club is self-limiting in that not a great many people have a special desire to study weather. The group might well number more than fifty and still do good work.
- (8) Due to the variety and amount of work that must be done there is no room for loafers. Each member takes his turn at reading the instruments and making the daily reports. In addition to his assigned work each member is trying to pass the tests that will promote him from a Cub Observer to a Junior Observer and higher.
- (9) The membership campaign was conducted by two boys who were instrumental in organizing the club. They presented a dialogue at our "Activities Assembly." In it they set forth the aims and objectives of the club, the sponsors, activities, and the like.
- (10) The club meets on school time during an activities period. The meetings are always held on school premises, partly because of having a place on the schedule and partly because the instruments belong to the school.
- (11) The club is financed by the school's general fund. The U. S. Weather maps are gotten daily for use in the Forecasting group. Money is also appropriated to the Instrument Makers for materials with which to work.

- (12) A very interesting stepping up program has been devised and revised from time to time as occasion required. As the program now stands, the following are the divisions together with their requirements:

Cub Observer

- 1 Ability to read a thermometer.
- 2 Ability to read a wet-dry bulb thermometer and determine relative humidity.
- 3 Ability to convert degrees C to F and F to C.

Junior Observer

- 1 Ability to read mercurial barometer.
- 2 Ability to identify clouds.
- 3 Make a weather forecasters wheel.
- 4 Knowledge of a selected list of meteorological terms.

Forecaster

- 1 Ability to interpret a weather map.
- 2 Knowledge of how weather instruments work.
- 3 Practice forecasts 40% correct for a period of one month.
- 4 Ability to determine wind direction and velocity.

Master Forecaster

- 1 Practice forecasts 60% correct for one month.
- 2 Preparation of a weather map.

INTERNAL ORGANIZATION

The Weather Forecasting Club has only three officers: a president, vice-president and secretary. These officers were chosen after the club members were thoroughly acquainted with each other. The duties of each officer are the usual ones excepting that the secretary keeps a record of each member's progress through the various degrees of the club. Officers are changed each semester.

A most interesting feature of this club is the close relationship to the Weather Instrument Makers Club which is sponsored by a Practical Arts teacher. This group makes very fine instruments based on plans taken from the *Popular Science* magazine. The money for materials is paid out of the school treasury and the instruments become the property of the school.

There is a club library made possible by the cooperation of the Allentown Public Library, the Raub School Library, and a number of teachers of the Raub School.

ACTIVITIES

The activities in which the club members engage were mentioned under the stepping up program. To the requirements for the various levels of the club might be added these:

- 1 Discussion of weather conditions.
- 2 Issuing of a daily weather report in the school's daily announcement sheet.
- 3 Keeping a weather log.
- 4 Movies on weather.
- 5 A club history is being prepared by a committee. In it can be found the dates when the various instruments were completed and installed. It also contains clippings and other items pertaining to the club.

All of the activities, it will be seen, are leading directly toward the purposes for which the club exists; namely, deepening, widening, and broadening of interests, and service to school and community.

**ELEMENTARY SCIENCE EXHIBIT
AT DRAKE UNIVERSITY**

The Elementary Science Exhibit held in the General Science Rooms at Drake University was visited by from 100 to 1100 teachers who attended the Iowa State Teachers Association November 5, 6 and 7.

Miss Lillian Hethershaw, head of the General Science Department at Drake University, was chairman of the exhibits. Over 400 persons attended the program of the Elementary Science Section held at Drake University.

The program was as follows:

1. "Integration of Elementary Science with other Subjects in the Primary Grades." Elsie Sindt, Primary Supervisor, Waterloo (West), Iowa.
2. "Experiences in Establishing an Elementary Science Curriculum." Burris E. Beard, Supt. of Schools, Webster City, Iowa.
3. "How Fur-bearing Animals Spend the Winter." Lillian Hethershaw, Professor of General Science, College of Education, Drake University, Des Moines, Iowa.
4. Business meeting.

Pupil activities in Science from the Kindergarten through grade six from the following school systems were on display: Atlantic, Chariton, Davenport, Des Moines, Knoxville, Indianola, Newton, Waterloo (East), and Waterloo (West).

Reference books for pupils on seed distribution and fur-bearing animals were on display.

The officers were: President—Stella E. Bushnell, Waterloo, Iowa. Secretary—Fern Kratzer, Newton, Iowa.

This was the fifth program and exhibit of Elementary Science Section of the Iowa State Teachers Association and the attendance has grown from about 75 to 1100.

CORRELATION BETWEEN GENERAL CHEMISTRY IN THE HIGH SCHOOL AND UNIVERSITY*

BY ALBERT E. GOLDSTEIN

*Assistant Professor of Chemistry,
Washington University, St. Louis, Missouri*

Much deliberation has been given to the subject of correlation of high school and university chemistry and much has been written about it in the literature of chemical education. The interest in this correlation is chiefly on the part of the teachers of chemistry in the colleges and universities. This interest, it is stated, is based on their desire to know specifically what has been taught in the high school course in chemistry so that duplication of effort may be avoided, so that the interest of the college freshman in chemistry may not be stifled by needless repetition, and that the high school student and teacher may not be discouraged by the knowledge that they are learning and teaching subject matter which is to be repeated in college.

In a report by the Committee of Chemical Education of the American Chemical Society on the subject of correlation of high school and university chemistry appearing in the *Journal of Chemical Education* (Vol. 4, pp. 640-656 (1927)) there is to be found a comprehensive outline of subject matter for courses in high school and university chemistry, and also the following concluding remarks appear, "The Committee wishes to reiterate and emphasize that it is not the purpose of the foregoing syllabi to standardize the teaching of chemistry. . . . If, however, a course in high school chemistry can be made to mean something definite which the colleges may take for granted in the same way that they do high school English and mathematics, for instance, and if unnecessary duplication of effort can be eliminated to an appreciable extent, much will have been accomplished." I wonder whether this is not the usual case of imagining one's neighbor's grass to be greener and whether the college teachers of mathematics and English feel that they may take for granted that every freshman brings with him "something definite" in their respective fields of endeavor.

I believe, as do many others, that *correlation*, to accomplish its intended purposes, means *standardization*—standardization

* Read before the Chemistry Section of the Central Association of Science and Mathematics Teachers, St. Louis, Nov. 27, 1936.

not only of content but of method. I believe also that standardization is neither advisable nor feasible. The improbability of either prescribing or making effective any successful system of correlation is so great that the whole matter of correlation may be classed as idealistic rather than realistic. I would heartily recommend abandoning all attempts at any comprehensive plan of correlation. There are many more or less apparent reasons for this point of view.

In the News Edition of Industrial and Engineering Chemistry (April 20, 1936) there appears the report of a committee assigned to the task of studying, among other things, the high school teaching environment of students who may be expected to matriculate in our colleges and universities. The committee ventures to submit the information that there is an almost general unanimity of opinion among university professors of chemistry, physics, biology and mathematics that the high school students who are now entering our universities, and who have entered within the last ten years, are much inferior in preparation in mathematics and other fundamental and basic courses to similar students of a generation ago, and that the situation is tending, if possible, toward a worse condition. The report then offers data gathered from studies made by other organizations such as the American Association of University Professors, the Office of Education of the Department of the Interior, and by the North Central Association. Some of the statistics cited are as follows:

(1) Of 5481 science teachers in North Central Association schools, 50.5% of the men physics teachers and 61.1% of the women physics teachers had had less than 11 undergraduate hours in physics; 12.2% of the men chemistry teachers and 19.3% of the women chemistry teachers had had less than 11 undergraduate hours in chemistry.

(2) In Minnesota, over one-third of 66 chemistry teachers had had less than 12 semester hours of specific subject matter preparation for their teaching.

(3) In California, 115 out of 855 science teachers, or 13.45%, had no college training in the subject they taught.

(4) In North Dakota there were 678 classes conducted by teachers who had had no college training in the subject matter they taught.

Other similar data are cited, sufficient to prove that any

highly developed plan of correlation must inevitably fail if *any* of those who are to carry out the plan in the high schools are totally or insufficiently prepared to do so.

Furthermore, similar syllabi put into the hands of a group of teachers, all adequately prepared, would be interpreted and taught differently. Also, the wide variation in physical equipment in different high schools would tend toward the same divergence in "the something definite" which any plan of correlation would aim to attain as its result.

I do not feel that I can subscribe to the general unanimity of opinion that high school students are more poorly trained today than ever before. Perhaps those who hold this opinion lay too much stress on the importance of subject matter. But lest this lead us too far afield and into a consideration of the applicability of mental hygiene to high school chemistry, let me return to my subject.

Since correlation, interpreted as standardization, is impracticable, what are the alternatives? First, I might suggest the inauguration of a complete change in the handling of the subject matter of chemistry in the high school.

Since only 10% of high school chemistry students are preparing for college entrance, it is entirely unreasonable to demand of the high school teacher that this 10% be taught at the expense of the 90% who would be more interested in chemistry as a cultural subject. It is my opinion that no college should allow college credit for high school chemistry. On this basis, assuming that the College Entrance Examination Board will yield and will change the nature of their examinations, an entirely different kind of chemistry could be taught in the high school. It should not be the function of the high school to begin professional training at that level. Baldly stated, *I think the high schools should teach less chemistry but more about chemistry.* Certainly it would be better, and fairer to those who do not intend to enter college, to give a course in pandemic chemistry rather than the introductory course which is now taught. A course of this nature would surely interest the majority. It would point out to them the part that chemistry has played in the development of our modern civilization, the part that chemistry plays in industry today. It would be a study of the economic and social implications of the subject. It would of necessity contain much of the fascinating history of the early development of chemistry. In fact, I feel it is an essential part of

a comprehensive cultural education and is invaluable to every man. The inauguration of this type of chemical education in the high school would create the necessity for an adequate textbook for the students to use. It also implies the need of teachers competent to give instruction in the subject.

Although the foregoing is my earnest opinion, I am not enough of an optimist to hope for such changes in the very near future. Therefore, I present the second alternative—not a theoretical one but an actual one, put into practice in one of the courses in general chemistry at Washington University several years ago. No precisely similar procedure is to be found described in the literature, and I am not aware that the plan is being employed elsewhere.

The class with which this plan was first used had an enrollment of 155 freshmen, coming from 43 different high schools in ten different states. Of these, 85% came from the high schools of metropolitan St. Louis. Those who had had chemistry in the high school constituted 70.4% of the class. This particular course is scheduled for three one-hour lecture periods and two three-hour laboratory periods per week during the first semester. One hour of the laboratory time is used each week for recitation. During the second semester the same amount of time is devoted to laboratory work in qualitative analysis and the lecture hours are reduced to two. One lecture period is devoted to the chemistry of the metals and the second to the principles and theories of qualitative analysis. The plan which I shall describe is limited to the first semester only, in this particular course.

All students registered in the course attend the same lectures. It is not believed that differentiation between those who have had high school chemistry and those who have not is advisable as far as lectures are concerned. By using an approach which is essentially that of physical chemistry, the student soon loses the notion that the subject is either a continuation course or a correlation course of the high school course in general chemistry. His interest does not flag, he soon overcomes all feelings of overconfidence and he may even enjoy his work.

The chief difficulties arise in the laboratory. Here, if called upon to repeat experiments previously performed in high school, the student rebels, and rightfully so—at least in some cases. But to assume arbitrarily that every student who has studied high school chemistry has had and has utilized the opportunity to prepare oxygen, hydrogen, chlorine, carbon monoxide, etc.,

and to study their properties, is fallacious. Therefore, it became necessary to evolve a plan for conducting the laboratory work which would take care of these, and many other, considerations.

For those who have not had chemistry, assignments are posted covering each month's work, and the quantity of work to be completed at each laboratory period is designated. The directions for the experiments to be performed are contained in a laboratory manual supplied by the chemistry department. These experiments are descriptive in many cases and quantitative in others. In all, it is believed that they will give the student who has not studied chemistry previously a well rounded experience in general chemistry.

For those who have had high school chemistry, some of these experiments are required, and are so designated on the assignment notice. These constitute about two-fifths of the total for the semester. All other experiments may or may not be performed, the decision resting entirely with the student. He is informed at the beginning of the course, however, that his decision should be determined by his past experience and that he may do any he desires; but logically he *should* desire to do those which he has never performed before. As soon as the student feels ready, he presents himself to the instructor for an oral examination on the assignment for the week. It takes but a few well devised questions to determine whether the student has, at some time in the past, performed the specified experiments. If this examination is satisfactorily passed, a "Special Exercise" is assigned. A set of "Special Exercises," twenty-five in number, have been prepared. They are all quantitative experiments and involve the use of an analytical balance. They do not purport to be unique, but consist of the usual determinations of equivalent weights, molecular weights, freezing point, etc., such as are to be found in most laboratory manuals.

With twenty-five "Special Exercises" available for laboratory sections of fifty students, not more than two students in any section are working on the same experiment during the same period. These experiments are assigned one at a time to each student and in no logical order; with the result that there is the possibility that all twenty-five may be in progress at the same time in one laboratory section.

A specific illustration may serve to point out some of the possibilities of this procedure. A student who has had high school chemistry may be assigned a "Special Exercise" on the

determination of the equivalent weight of a solid acid. This may occur in the very first week of the semester and the student may know nothing about equivalent weights. However, it is assumed that, having had sufficient chemistry to understand the language of chemistry, he can intelligently make use of the reference books made available to him by the instructor and can *dig out* for himself all of the information necessary for an understanding of the experiment at hand.

As soon as a student has acceptably completed one "Special Exercise" he is given another. Each week, however, at the first of his two laboratory sessions he is to pass an examination on the posted assignment for the week, which may be looked upon as the minimum essential expected of him. Insofar as the directions for these "Special Exercises" are rather brief and do not in any case give diagrams or drawings of the set-up of the apparatus used, the student is called upon to use some ingenuity and resourcefulness. As a matter of safety, all set-ups are shown to an instructor before being used.

Just what does this plan aim to accomplish? It makes unnecessary the repetition of experiments performed in high school. It aims to hold the student's interest; to encourage initiative and self-reliance, the ability to think, and the ability to seek out reference material. It aims to develop greater skill in laboratory manipulation. It aims to give to the student a richer experience and a better understanding, according to the limits of his own capacities. It likewise aims to teach through chemistry the scientific method of thinking. It recognizes individual differences and makes it possible for each man to proceed in accordance with his own individual aptitude and ability. It disposes of regimentation.

The working of the plan may be shown by the following statistics, gathered during the first year of its use.

TABLE I

Semester Grade	A	B	C	D	F
Number of Students	20	25	45	10	9
Special Exercises Completed:					
Maximum Number	19	14	8	3	4
Minimum Number	2	2	0	0	0
Average	7.5	6.7	3.6	1.9	1.0

The wide divergences between the maxima and minima in the

first two groups may be explained in several ways. They are due primarily to the fact that many of these students, realizing the inadequacy of their previous laboratory experience, found it advisable to do most of the work which was not required; they are due to differences in innate ability; they are due to the fact that many were sufficiently stimulated by the opportunities offered by the plan to spend much of their free time in the laboratory.

This procedure in the laboratory, coupled with a lecture course different in nature from that of the high school, makes unnecessary any attempt at a more comprehensive scheme of correlation. Its chief weakness is the heavy load it places on the laboratory instructor. However, our experience has been that the instructors are perfectly willing to give unstintingly of themselves because they sense the eagerness with which the great majority of the students accept the entire plan. It is sufficient inspiration for any instructor to have his students anxious to spend their leisure hours in the laboratory learning more than the specified minimum necessary to just barely pass the course.

THE WATER CYCLE

The following "poem" THE WATER CYCLE was composed by the pupils of Mrs. Caroline Dexter's 7B Class in the Concord School No. 18 of Rochester, New York. These children receive their science instruction by radio. The class room teachers are encouraged to correlate the science work with other subjects such as art, English, reading, and arithmetic etc.

HARRY A. CARPENTER
Specialist in Science
Rochester Schools

Little drops of water
Upon a blade of grass,
Mother Nature turns the heat on
Puff! They are gas.

As they're rising upward
They will all expand,
But you cannot see them
Nor feel them with your hand.

Up among the clouds then,
Is their destination.
Mother Nature takes the heat away
Splash! Condensation.

PLANT HORMONES¹

BY WILLIAM J. ROBBINS

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For many years botanists have been interested in the study of tropisms, which are growth curvatures in response to the unilateral stimulation of an organ. For example, the shoot of a seedling laid in a horizontal position grows up and the root grows down in response to the unilateral action of gravity. This is a tropism, geotropism. A plant illuminated from one side grows toward the light. These tropisms are commonly known and form a part of the material presented in almost all courses which deal with plants. But what happens in a tropism, where does the bending occur, what is the relation between stimulus and response, where is the stimulus perceived, is the stimulus transmitted and if so where and how? Many of these questions have been answered but an explanation of what really occurs in phototropism and geotropism has come within the last few years.

It now appears that definite chemical compounds formed in the shoot tip are necessary factors for the enlargement of the cells in the growing region of the stem. These substances, variously named growth hormones, auxins, growth regulators or phytohormones are necessary for the enlargement of the cells in the stem. If the shoot tip is cut off the stem ceases to elongate because the source of the growth hormones has been removed. When the shoot is exposed to one-sided illumination the growth hormones accumulate on the shaded side of the shoot tip, move down the stem, cause a greater elongation of the shaded side than the lighted side and so the shoot bends toward the light. In a horizontally placed shoot gravity causes more of the hormone to accumulate in the lower side of the shoot, growth is accelerated on the lower side and the shoot grows up. The growth hormones, however, appear to decrease the growth of the root. In a horizontally placed root the growth hormones accumulate on the lower side of the root, decrease the rate of growth there as compared to that of the upper side and so the root grows down.

¹ Read before the Biology Section of the Central Association of Science and Mathematics Teachers, St. Louis, Nov. 27, 1936.

Three such substances have been isolated in crystalline form from plants. They are

auxin a

auxin b

heteroauxin or 3-indole acetic acid

Their chemical formulae are known and one at least, heteroauxin, can be readily purchased either as pure crystals or in a paste made with lanolin. Using these preparations it is easily possible to demonstrate the effect of heteroauxin on bending. A stem smeared with lanolin containing a suitable concentration of heteroauxin will bend away from the treated side, thus imitating what occurs when the stem is illuminated from one side or laid horizontally. Hitchcock, Zimmerman and Wilcoxon have found several other compounds which will induce the same response, though whether they are formed in plants and responsible for tropisms we cannot say. These compounds will not only induce bendings, they will cause epinasty of the leaves, swellings and proliferations on the stem and the production of adventitious roots, a fact of great practical significance since it may be of importance in the propagation of plant cuttings.

Other plant hormones than those to which I refer have been hypothecated including cell division hormones, root forming hormones, reproductive hormones; and for some there is accumulating considerable positive evidence. That for the existence and functioning of the auxins involved in tropisms is most complete.

It is not my intention to present here a complete account of our present knowledge of phytohormones but by discussing their discovery to illustrate certain fundamental principles regarding the growth of scientific knowledge.

The word hormone derived from the Greek *ὁρμω* and meaning "I activate" was suggested by Hardy and first applied in animal physiology in 1906. It was used to describe any substance normally produced in the cells of some part of the body and carried to distant parts which it affects though present in very minute amounts. While the term was devised for certain phenomena in animal physiology and the first hormones were identified and isolated from animals the concept dates from the botanist Sachs (1881) who hypothecated what he called "formative stuffs" which he believed were produced by the leaves, moved to the growing points and caused the mass of plastic

material there to assume its final form, flower, leaf and so on. Although hormones were thus first suggested in the plant kingdom experiments designed to prove or disprove their existence there by a direct attack upon the problem were suggestive but not definitive. Our present information on plant hormones is largely an outgrowth of a study of the growth movements of plants in response to light.

The classical material for the investigation of phototropism has been the oat seedling. When an oat seedling germinates the first part to appear above the ground is a hollow cylindrical sheath, the coleoptile, within which are the young leaves. When the coleoptile reaches about the size of a match stick the first leaf pushes through the apex and the coleoptile remains for some time as a sheath about the base of the young plant. Oat grains germinated in the dark have vertical coleoptiles which are yellowish white in color. Exposed to one sided illumination those etiolated seedlings bend toward the light. Germinated in a dark box with a small hole to admit light each coleoptile will point toward the hole with uncanny accuracy, a point originally emphasized by Darwin.

From a practical standpoint, from the standpoint of plant production, the study of the bending of oat seedlings to light is of little apparent significance and the contributions made to phototropism in this country where physiological botany has been largely dominated by its agricultural implications, have been minor and on the whole unimportant. But abroad many men have been interested in the phenomenon for various non-utilitarian reasons and a considerable amount of information regarding the phenomenon has been accumulated.

The first bit of information on phototropism likely to impress us is the extreme sensitiveness of the plant to light. In his book on *Power of Movement in Plants* published in 1882 Darwin describes in his painstaking fashion experiments in which the seedlings of *Phalaris canariensis* curved toward a small lamp at a distance such that "we could not see a circular dot 2.29 mm. (0.99 inch) in diameter made with India ink on white paper."

The sensitiveness of plants to light was investigated by many others since Darwin's time. Blaauw (1909) found that etiolated oat seedlings would bend toward light of an intensity less than 0.001 that of full moonlight and seedlings of *Vicia sativa* are even more sensitive than those of oats.

The chief facts on the phototropism of oat seedlings with which we are acquainted may be briefly stated

1st. The oat coleoptile is extremely sensitive to light.

2nd. Oat seedlings grown in the dark exposed for a brief period to light coming from one side and again placed in darkness will later bend toward the side which had been illuminated. In other words the time required for perception of the stimulus and the time required for the response to it are not identical; the perception of the stimulus and the response to it are separate and distinct phenomena.

3rd. The perception of the stimulus depends both upon the intensity of the light and the time of the exposure; the weaker the light the longer the exposure necessary to produce a response and the stronger the light the shorter the exposure necessary. Blaauw (1909) found that a light somewhat less than 0.001 that of full moonlight required 43 hours exposure while 0.001 second was a sufficient exposure if the light were about half the intensity of full daylight.

4th. The extent of the response varies with the quantity of light and the reaction time also depends to some extent upon the amount of the stimulus.

5th. The tip is the part of the coleoptile most sensitive to light. It may be compared in some respects to a sense organ. It is the perceptive region of the coleoptile. Darwin found this to be true by a simple but ingenious experiment. He covered the coleoptile tips of oat seedlings by caps of black paper, tin foil or blackened glass and discovered that such coleoptiles would not bend toward light from one side even though the lower part of the plant was illuminated. Sierp and Seybold (1926) and Lange (1927) investigated this question much more elaborately and accurately. He (Lange) found the first 0.1 mm. of the tip was almost 1000 times more sensitive than the ninth 0.1 mm. and the first 1 mm. was almost 2000 times more sensitive than the third mm.

6th. The phototropic response is due to unequal growth (elongation) of the two sides of the coleoptile. The shaded side elongates more rapidly than the lighted side, thus bending the plant toward the light.

7th. The stimulus, which is perceived primarily by the tip of the coleoptile, travels downwards, the major bending occurring in the base of the coleoptile. If we may compare the tip

to a sense organ, then the basal portion might be compared to a motor organ. The stimulus perceived by the tip is transmitted downward to the base where it causes the major movement to occur.

But what is the effect of light on the tip and how is the effect transmitted down the coleoptile? What is responsible for the shaded side growing more rapidly than the illuminated side?

No answer for these questions supported by experimental evidence was forthcoming until 1910. In that year Boysen-Jensen of Copenhagen reported some simple but fundamental experiments which suggested that phototropism was the result of the movement of water-soluble growth-stimulating substances from the illuminated tip. He made horizontal cuts about halfway through the coleoptile tip three or four millimeters from the apex. In some he inserted a thin piece of mica or platinum. He then illuminated the tip. If the cut was on the illuminated side a bending toward the light occurred. If the cut were on the shaded side there was no response. The conclusion drawn was that something which would not pass platinum, mica or a dry cut moved from the illuminated tip down the shaded side and caused the lengthening of that side and the bending toward the light.

In addition to these experiments Boysen-Jensen performed one still more enlightening. He severed the tip completely, covered the decapitated base with gelatine and replaced the tip. When the tip of such a plant was illuminated it bent toward the light. This showed clearly that the effect of the stimulus is transmitted over a discontinuity.

It is worth noting that Boysen-Jensen tried these experiments in spite of the fact that Fitting in 1907 had reported somewhat similar experiments with negative results, probably because the experimental plants were kept in too moist an atmosphere. Under such conditions the cut was filled with water through which the active substance could diffuse. This is worthy of note because it shows the way in which we gain scientific knowledge. In science no man's word is taken as law. What he states as truth must be susceptible of confirmation by others and until it is tested and confirmed we view it with reserve. In accordance with that principle Boysen-Jensen repeated Fitting's experiments and in turn the botanical world was slow to accept Boysen-Jensen's experiments at their face value.

But confirmation followed. Paál (1914, 1918) confirmed and

extended Boysen-Jensen's experiments and showed further that in the dark an amputated tip set on one side of a decapitated base would cause curvature away from the side on which the tip rested.

Stark (1921) and Stark and Drechsel (1922) substituted the tip from a coleoptile stimulated by one-sided illumination for the tip of a plant not so stimulated. When this was done the base of the unstimulated plant on which the stimulated tip rested responded as though it had actually received light. They found also that the tip of one kind of plant could be substituted for another.

Purdy (1921) repeated and confirmed Boysen-Jensen's original experiments and extended them to the phenomenon of geotropism.

Söding (1923) observed that a decapitated oat seedling without a tip grew about one-third as much as a decapitated seedling on which the severed tip had been replaced.

Snow (1924) showed that it was possible to produce a bending away from the light if a severed tip was placed on one side of the base and illuminated from that side.

Boysen-Jensen and Nielsen (1925) found that the light was probably effective, not by destroying the growth substance on the illuminated side or by changing the rate of its movement down the coleoptile but by affecting its movement crosswise; away from the lighted side and toward the shaded side. They split the coleoptile tip lengthwise and inserted a thin piece of glass. When such a tip was illuminated perpendicularly to the glass no response occurred. This was interpreted to mean that the growth substance moved transversally in the tip but could not pass the glass barrier. When the tip was illuminated with the glass plate parallel to the light the response was normal.

Stark (1921) and Seubert (1925) showed that it was possible to affect the bending of coleoptiles by placing blocks of agar containing tissue extracts, certain salts, diastase or saliva on one side of the decapitated base of an oat coleoptile.

And thus in the years since Darwin's study of the power of movement in plants more and more complete and accurate information on the phototropism of oat coleoptiles accumulated. We continued to learn more and more about less and less; a procedure frequently criticized by socially minded administrators and others, who would apparently prefer to have less and less learned about more and more—a process which I must

point out approaches as a limit complete ignorance about everything.

No one knows how much time has been devoted to the study of the responses of this small object to light. Perhaps 500 man years have been expended on it and if we consider that each investigator must have had preliminary education and training and that minds above the average in intelligence have been devoted to it during their most active and productive years the above figures should probably be doubled or trebled.

I feel sure that many a practical man must have asked what difference it makes whether we know why oat seedlings bend toward light or not. They would still bend whether we know why they do it or whether we don't. I feel sure, too, that some of those working on the problem haltingly discoursed on the importance of knowledge, even of little things, of the value of truth, and of the significance of fundamental research.

At any rate the fundamental experiments of the Dane, Boysen-Jensen, demonstrating that phototropism was probably due to a diffusible substance and the further work of the Hungarian, Paál; the Germans, Stark, Drechsel, Söding and Seubert, and the English, Snow and Purdy, prepared the way for the final and complete demonstration by a Hollander, Went, of the existence in plants of growth substances or growth hormones. In truth science knows no national boundaries.

Although Boysen-Jensen's experiments of 1910 now seem so significant and convincing, not everyone was willing to accept them and the interpretations which Boysen-Jensen had placed upon them.

Brauner (1922) considered the process of bending in response to light to involve

- (1) Increase in permeability and increase of a growth inhibitor on the lighted side.
- (2) Movement of the growth inhibitor down on the lighted side to the growth zones.
- (3) Strong inhibition of growth on the lighted side.
- (4) Bending toward the light.

Priestley in 1926 said, "It may be permissible to point out what a pyramid of conceptions are struggling to maintain themselves upon the one general experimental fact—the phototropic response of a coleoptile stump when its severed apex is replaced and alone laterally illuminated."

Priestley then points out the frequency of the exudation of drops of water from coleoptile tips (guttation). He assumes the permeability of the apical tissues of the coleoptile to be increased by light, and, therefore, that light falling on the apex increases apical guttation. Lateral light falling on the apex he believed increased the rate of guttation on the lighted side, decreased the turgor and caused the bending toward the light. The results of the various decapitation experiments he considered explainable on the basis that decapitation opened the veins and increased water loss.

It remained for Went (1928) to give the final convincing evidence for the occurrence of growth accelerating substances in plants and their function in phototropism. But note how the way had been prepared for him by Boysen-Jensen's original fundamental experiments, by Paál's and Purdy's confirmation of them, by Stark's and Seubert's use of agar blocks, by the experiments of Snow, Söding and others. Furthermore, F. A. F. C. Went's laboratory in Utrecht, in which the son, F. W. Went worked, had for many years been concerned with a careful and extended study of phototropism.

Went showed that the active material would diffuse from the coleoptile tip into a block of agar, which would then act as effectively as the tip itself. He found it possible to determine the concentration of the growth hormone, by allowing it to diffuse into agar, and then measuring the amount of bending of the oat coleoptile under standard conditions. From its diffusion rate he calculated its molecular weight to be in the vicinity of 376. He demonstrated that the concentration in the tips of illuminated coleoptiles was less than in those left in the dark, and that there was less on the illuminated side. The great contributions of Went were first, the final demonstration of the growth substance and second, his method of quantitative determination by the use of agar blocks placed laterally on the decapitated base of oat coleoptiles under standard conditions.

From this time on a widening circle of investigators busied themselves with the problem.² Nielsen (1930) found that *Rhizopus suinus* and other molds produced an active substance. Boysen-Jensen (1931) found that bacteria also produced it, Dolk and Thimann (1931) that the active substance in cultures

² No attempt has been made to give a complete summary of the voluminous literature on plant hormones. The reader may be referred to the translation and revision by Avery and Burkholder of Boysen-Jensen's book on Growth Hormones in Plants. McGraw-Hill. New York.

of *Rhizopus suinus* is an acid with about the dissociation constant of acetic acid. Kögl, Haagen-Smit and Erxleben (1931, 1933) found active substances in urine and eventually isolated (1934) three materials in crystalline form, Auxin a, an organic acid of molecular weight 328; Auxin b, a lactone M. W. 315; and heteroauxin or 3-indole acetic acid. Laibach (1932) found considerable quantities of growth hormone in the pollinia of tropical orchids. He prepared (1933) a paste of lanolin containing an acid extract of the pollinia and found the paste effective in causing curvatures. Heyn (1930) found that the growth substance was chiefly effective in increasing the plasticity, or ease of stretching, of the cell wall. Skoogg and Thimann (1933, 1934) reported that auxin a, auxin b and heteroauxin had the same inhibiting effect on the development of lateral buds as does the terminal bud. Avery (1935) found the auxin concentration associated with the differential growth in tobacco leaves. Boysen-Jensen (1934) and Hawker (1932) found the differential distribution of auxin under the influence of gravity to be responsible for the movements of roots in response to gravity. Bouillenne and Went (1930) found boiled malt diastase, extract of rice polishings and water extract of cut leaves induced root formation. Thimann and Went (1934) observed that crude auxin preparations from *Rhizopus* and from urine were effective in inducing the formation of adventitious roots. Thimann and Koepfli (1935) found pure 3-indole acetic acid effective. Zimmerman, Wilcoxon and Hitchcock (1935) extended the number of substances which induce curving, overgrowths, epinasty and root formation and used them in both liquid form and in lanolin.

Are these substances, 16 or more, all to be considered plant hormones, or are they effective by influencing the production or functioning of specific growth hormones themselves? How does light cause the lateral movement of the growth hormones in the coleoptile tip? Are there other hormones which affect cell division or the differentiation of plant parts such as flowers? Why do the same substances accelerate the growth of stems and inhibit the growth of roots? How is it possible for the same substance to inhibit the elongation of roots but to favor the initiation of adventitious roots? Are dwarf varieties of plants the result of a deficient production of the growth hormone? For these questions and many others on the phytohormones we have as yet no answer. Scientific knowledge is rarely complete, rarely free from error.

This history, brief and fragmentary as it is, demonstrates that scientific knowledge accumulates slowly; that it does not spring full-formed from the mind of any one individual, but is the result of the contributions of many. Each of this series of investigators to whom I have referred might well repeat the words of the poet:

"I caught the fire from those who went before,
The bearers of the torch who could not see
The goal to which they strained. I caught the fire,
And carried it, only a little way beyond."

What I have said is one more illustration that the search for truth may yield significant practical applications in unexpected places. Did Darwin have in mind the rooting of lemon twigs when he studied the movement of coleoptiles to light? Did Boysen-Jensen perform his experiments with the idea of making the propagation of cuttings more certain? Of course, neither had in mind any such applications of the results of their work. Both were interested primarily in satisfying their curiosity about certain fundamental natural phenomena. The history of science is full of such examples in which the discovery of truth yields unexpected and unanticipated practical applications.

DEMONSTRATING THE LAW OF CONSERVATION OF MATTER

BY FRANK COOK

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The experiments usually listed for demonstrating the law of conservation of matter lack the happy combination of a bit more than tolerable accuracy and facility and expediency of performance. Obviously, the advantages of the demonstration described here over the solution-mixing or candle-burning method require no mention.

A photoflash bulb* is weighed on an analytical balance. It is screwed into a 110 volt socket, and a flash brilliantly displays the combustion of the metal foil. The bulb is permitted to cool and again placed on the pan. The balancing point remains the same as before combustion; and hence, mass was neither lost nor gained.

Possible error may be due to handling of the bulb with moist hands and/or the picking up of matter by the base of the bulb from a dirty socket.

* Can Be purchased at any camera shop or drug store handling photographic material for about 15 cents.

EVALUATING APPRECIATION OF THE CULTURAL VALUES OF MATHEMATICS¹

BY MAURICE L. HARTUNG

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I. SOME PROBLEMS WHICH MATHEMATICS TEACHERS MUST FACE

Teachers of mathematics are frequently asked: "Why should secondary school pupils study mathematics?" or more specifically, "Why should a person study plane geometry?" Sometimes the question is asked by a school administrator or general educator, sometimes by a parent, often by the pupils. If these questions are asked in good faith, what the questioner really wants to know is essentially this: "How does a pupil who has studied geometry differ from one who has not? What changes in behavior does this course bring about?" When the question is phrased in this way, many of us are likely to find ourselves in an embarrassing situation. If we cannot give a straight-forward and precise answer, our inquisitor may conclude that there *are* no good reasons for studying geometry. If he is an unsympathetic critic, he may even infer that most pupils should not study demonstrative geometry. If the teachers are unable to describe some desirable changes resulting from their courses, then such an inference is perhaps justified. The naive assumption that undefined or loosely defined but worth-while changes in pupils will take place automatically is a weak foundation on which to build a sound curriculum. Most of us, however, are able to phrase some sort of description of changes we hope to bring about. In the course of making this effort, we suddenly realize that what is wanted comes under the heading "Objectives." Once this association has been made the going becomes easier, and we state, for example, that one of our most important objectives is "development of the ability to do logical reasoning."

The time available does not permit a complete discussion of all of the objectives which are classified as cultural. The Report of the National Committee says:

"By cultural aims we mean those somewhat less tangible but none the less real and important intellectual, ethical, esthetic or spiritual aims that are involved in the development of appreciation and insight and the formation of ideals of perfection. As will be at once apparent the realiza-

¹ Read before the Mathematics Section, Central Association of Science and Mathematics Teachers, St. Louis, Nov. 27, 1936.

tion of some of these aims must await the later stages of instruction, but some of them may and should operate at the very beginning.

"More specifically we may mention the development or acquisition of

- (1) Appreciation of beauty in the geometrical forms of nature, art, and industry.
- (2) Ideals of perfection as to logical structure, precision of statement and of thought, logical reasoning (as exemplified in the geometric demonstration), discrimination between the true and the false, etc.
- (3) Appreciation of the power of mathematics—of what Byron expressively called "the power of thought, the magic of the mind"—and the role that mathematics and abstract thinking, in general, have played in the development of civilization; in particular in science, in industry, and in philosophy. In this connection mention should be made of the religious effect, in the broad sense, which the study of the infinite and of the permanence of laws in mathematics tends to establish."

Let us briefly consider the first. What sort of things does a person who appreciates the beauty of geometric form do? Assume for the moment that we know the answer to this question. Is this behavior produced by the pictures and designs in our textbooks? Is it produced by having the pupils make a few geometric designs? How many of us have any recorded evidence on these questions? A year and a half ago, I began an analysis of this objective in terms of behavior and made some progress toward the development of tests for the objective. But the number of teachers who are really concerned about it is probably small, and these problems have temporarily been laid to one side.

Under the third cultural objective mentioned above, the National Committee refers to the development of a realization of the role that mathematics has played in civilization. Many teachers have said that this is one of their objectives but I know of only a few who are trying to find out if their pupils develop such a realization. One of them is Mr. Gaylord Montgomery of the John Burroughs School of this city. A year ago, we began to study this problem and to date we have tried two different test techniques. There is a noticeable lack of suitable instructional materials for this objective. Most of the available discussions which attempt to bring out the role of mathematics in civilization are written for educated adults, not secondary school pupils. This illustrates the fact that when we really begin to study these questions, we discover ways in which our present courses and materials may be improved.

When the title of this paper was chosen six months ago, I planned to discuss these objectives at greater length. As the

time of the meeting approached, however, it seemed best to discuss one objective rather completely. Because probably more teachers are interested in the objective which relates to logical reasoning than in the other two, it has been chosen for more extensive treatment. Before entering upon this discussion, however, we should note that the statement of the National Committee does not define the expected changes in pupils clearly enough either to satisfy a serious critic of our courses or to serve as a practical guide to the classroom teacher. When we mention "development of ideals of perfection as to logical structure" do we mean *with respect to the materials of geometry* or do we mean with respect to other types of reasoning situations such as the pupils meet outside of class? What does a good reasoner do that a poor reasoner does not do? Our beliefs about these matters have usually been shrouded in statements too vague and too general to be translated into effective action. Yet we base our defense on the value of these intangibles, and we admit that present tests tell us little about their achievement. We must face the problem of defining our objectives more explicitly if we are to satisfy our critics.

Perhaps I should present briefly some of the other reasons why we need more precise statements of objectives. I have indicated above that we need to be better prepared to explain our aims to others—for example, to parents, to our high school principals, and to our pupils. These people all have a right to know the changes in pupils which should result from the expenditure of time and effort required by our courses. It is our duty and our privilege to tell them, but we must be able to do so in terms sufficiently explicit that they can recognize that the proposed results are valuable. Secondly, we need precise statements as a basis for guidance of our own procedures. We must daily decide what to teach and how to teach it. It is questionable whether we can expect many of our important aims to be obtained by a blind following of the textbooks as they are now generally written. We need to find out whether other materials and other methods produce better results. This implies that we need more precise statements in order to have a basis for obtaining evidence that our objectives are being achieved. It seems to me that the kinds of evidence that we have been accustomed to give concerning the achievement of these so-called "intangible values" will no longer serve the purpose. We have too often resorted to mere statements of opinion. When we

have offered evidence, it has usually been meager and inconclusive. In order to be generally acceptable today, evidence must be objective and of sufficient quantity to warrant drawing generalizations from it which have a good chance of surviving if more evidence is obtained under the same conditions. Before leaving this particular theme, I would like to read to you a short quotation from John Dewey's famous book called "How We Think." In discussing "*the harmful consequences of vagueness*," Mr. Dewey says:

"Conscious distortion of meaning may be enjoyed as nonsense; erroneous meanings, if clear-cut, may be followed up and got rid of. But vague meanings are too gelatinous to offer matter for analysis and too pulpy to afford support to other beliefs. They evade testing and responsibility. Vagueness disguises the unconscious mixing together of different meanings, and facilitates the substitution of one meaning for another, and covers up the failure to have any precise meaning at all. It is the aboriginal logical sin—the source from which flow most bad intellectual consequences. Totally to eliminate indefiniteness is impossible; to reduce it in extent and in force requires sincerity and vigor."

Although we claim we are teaching logical reasoning, I think we have ourselves been guilty of what Mr. Dewey calls the "aboriginal logical sin." It is my belief that if we can obtain precise statements of our objectives and valid evidence that we are achieving them, many of the current criticisms of the teaching of mathematics may be eliminated.

What are some of the characteristics of a good objective? First, I have indicated that the objective should be worded in terms of the behavior expected of the pupil. Behavior is here used in the broad sense, meaning not only overt physical action but also mental and emotional reactions. A second characteristic of a good objective is that it should be sufficiently general that the behavior may be exhibited in a wide variety of different situations. On the other hand, the *wording* of the objective should be sufficiently specific that it gives some indication of the nature of the situations in which the behavior is to take place. For example, many social studies teachers have as one of their objectives, "the development of tolerance towards people of other races." Although this is certainly a worthy objective, the statement of it needs to be somewhat more specific in order to be a real guide to teaching. Thus it is probably a waste of valuable time to attempt to develop an attitude of tolerance toward the Eskimos simply because probably few of us will ever have an opportunity to be tolerant towards an Eskimo. If

the pupil does not have much chance to make use of what he has learned, the objective is open to criticism. A third characteristic of a good objective is that measurable *changes* in the behavior of the pupil should be observable between the beginning of his experiences in the course and the end. Unless we can show that the pupils are changed as a result of their experiences, we may have difficulty in justifying an objective, however worthy it may appear to be on philosophical grounds. There are other criteria for objectives which I shall not mention here.

Summarizing the discussion thus far, note that I have indicated two crucial problems facing mathematics teachers: (1) We must more carefully define the desirable types of changes we expect to bring about, and (2) we must obtain satisfactory evidence that these changes are taking place. One of the teachers who is making the most progress in this direction is Mr. H. P. Fawcett of the Ohio State University High School. Mr. Fawcett *has* clarified his objectives for his course on the "nature of proof," and he *is* obtaining evidence about the ability of his students to do logical reasoning in life situations. As a result, his work is receiving nation-wide attention. It is highly significant that many people who are severely critical of secondary mathematics as it is commonly taught are enthusiastic about his work. If all teachers will carefully state objectives which transcend the factual content and specific skills of their courses, and if they will undertake to get real evidence that they are attaining these general objectives, then they need have little fear that mathematics will lose its time-honored place in the curriculum.

II. A TENTATIVE STATEMENT OF SOME OBJECTIVES

Let us next consider a tentative statement of some objectives related to logical reasoning.

Given a situation in which reasoning is applicable,² (for example, in reading editorials or articles, or in listening to discussions or speeches which attempt to prove some point), the "good reasoner" tends consistently to exhibit the following behaviors:

1. If certain words and phrases appear to him to be loosely or ambiguously used, he either asks that they be carefully defined, or he defines them for himself, in each case recognizing that his conclusion depends upon the definition chosen.

² This discussion is limited to the *consumer* point of view. The behaviors exhibited by *producers* of logical reasoning are, however, similar.

2. He requires that the evidence and important assumptions on which the conclusion depends be explicitly stated; in some cases he attempts to make such statements for himself.

3. He analyzes and evaluates the items of evidence and the assumptions in an attempt to estimate the probability that they are valid.

4. If a conclusion is not given, he either

4.1 makes one which is logically sound, or

4.2 refuses to make one, or

4.3 makes one which is consciously tentative—
according as the nature of the situation warrants.

5. If a conclusion is given, he either

5.1 recognizes that it is sound, or

5.2 recognizes that it is fallacious, and (sometimes) substitutes a correct conclusion, or

5.3 recognizes that it is not conclusive—

in each case depending upon the nature of the situation.

6. He can indicate certain logical principles which apply to or underlie the process of arriving at the conclusion.

"Indicate" here means that if asked for reasons as to why he has exhibited one of the above types of behavior, he can frame an explanation in terms of logical principles or can check the proper principles among a list—i.e., he associates the behavior with a principle, and if he does not consciously *act* on the basis of the principle at any rate recognizes that the principle applies.

An example of a logical principle which is very commonly taught is the following: The converse of a given proposition is not necessarily true. I suppose that every geometry teacher attempts to drive this principle home. There are, however, many other principles which do not at present receive sufficient emphasis, but which it seems to me are understandings that a student may reasonably be expected to have at the conclusion of a course in geometry. Samples of such statements are the following:

A. The "If-Then principle"; i.e., in a logical argument, we do not assert that the conclusion is necessarily true, but only assert that if the assumptions on which the argument is based are granted, then the implied conclusion must be granted.

B. Crucial words or phrases must be precisely defined, and a changed definition will produce a changed conclusion although the argument from each definition is logical.

C. The validity of an *indirect* or *reductio ad absurdum* argument depends upon whether all of the possibilities have been considered.

D. A logical argument cannot be refuted by abusing the arguer, by "pooh-poohing" what he has to say, by attacking his motives, etc.

I think it is clear that the usual type of achievement test given in plane geometry gives us little direct evidence that our pupils understand these principles. Certainly these tests do not give us evidence concerning the ability to reason logically (as above defined) when one reads newspapers and magazines, or listens to sermons and political speeches.

The objective evaluation of reasoning ability in situations such as these is a field of investigation in which much needs to be done. I have recently spent a little time working on the problem, and with the help of an assistant, Mr. Walter Howe, have made a tentative test of this ability. Before discussing the test in some detail, it may be wise to explicitly mention some of the assumptions on which it is based.

III. IMPORTANT ASSUMPTIONS

A number of assumptions need to be kept in mind throughout the remainder of this paper. First, the discussion is restricted to geometry as a part of a *general education* rather than a part of the training for advanced work in mathematics or the professions. I am talking about geometry for the boy or girl who may never take any mathematics beyond what he gets in that course. Mathematics for these pupils may presumably be of a type different from that intended for those who expect to go on with further scientific study. It does not follow, however, that those who are going on with scientific study cannot profit by this kind of mathematics and postpone the learning of many of the technical facts and methods until more advanced courses. The value of demonstrative geometry as an element in general education depends largely upon its method of thinking about problems and its advantages as a vehicle for acquainting pupils with the nature of logical proof. The problem which mathematics teachers face is that of showing that the methods of thinking practiced in the geometry classes are transferable to life situations. The older theories of transfer of training have undergone revision in recent years. It is now recognized that transfer is

possible provided one makes the effort to generalize the experiences so that they *will* transfer. The problem is really that of showing how *much* transfer takes place. In order to do this, we must discover to what extent pupils use in situations outside the classroom the methods and principles which they have learned in school. One hypothesis concerning a possible method of increasing this transfer is that life situations in which reasoning is applicable should be discussed within the classes in geometry. This is now being done to some extent in a few schools, and I believe that the movement will gain strength during the next few years.

We assume that the objectives and principles listed above are sufficiently basic that few people will deny their validity. People may, however, differ widely in their beliefs concerning the methods and materials which should be used in teaching for these objectives. Some teachers may wish to rely solely upon geometric materials to achieve these results. Others may feel it desirable to discuss non-geometric materials in the classroom. Which of these methods is better should be decided on the basis of experimental evidence. The test I am about to discuss is one tentative means of obtaining such evidence. By concentrating upon the end-product or goal, rather than upon the specific curriculum (e.g., specific theorems and facts of geometry) which may be used in the teaching process, it is hoped that we may give individual teachers considerable freedom to adapt their courses to their local conditions. In other words, we are more interested in the extent to which the pupils attain the objective than the particular paths they follow in working toward it.

We are assuming, temporarily at least, that in order to get valid evidence about the ability to reason in situations met outside the classroom and with other than purely geometric materials, we must use test materials which approximate real life situations as nearly as possible. Some of the test items I will discuss therefore represent actual occurrences.

IV. SAMPLE TEST ITEMS

Limitations as to time will prevent the discussion of more than two or three examples. Probably the best way to construct items is to choose reasoning situations and ask the pupils to indicate which of several conclusions appears to be logical. They may also be asked to indicate their reasons for selecting that conclusion. Some of these reasons may then be included on a

new short-answer form so that when the test is given in the future instead of writing out their reasons, pupils need only place a check mark opposite the statement which best represents their thinking. Statements of several principles of reasoning which do not apply in a given item, but which are relevant to other items of the same test, may be included. It then requires greater discrimination on the part of the students in order to check the correct reasons.

The first sample item involves an application of the "If-Then principle."

The president of a power and light company wrote a letter to a newspaper. He said: "Let us assume the following statements are true. The Federal Government is building electric power lines which will compete with private power utilities in the Tennessee Valley. It is unfair for the Federal Government to compete with private power utilities."

Which one of the statements below then follows:

- 1. It is unfair for the Federal Government to build competing power lines in the Tennessee Valley.
- 2. It is quite fair for the Government to build competing power lines in the Tennessee Valley.
- 3. No conclusion can logically be drawn.

Check the statements you might use to defend your conclusion:

- a. The government will be doing a useful public service and should go right ahead.
- b. The power companies have a lot of money invested and the government will ruin their business.
- c. The word "utilities" needs to be more carefully defined.
- d. If a person accepts the original statements, then he must accept the conclusion which follows from them even if it is not necessarily true.
- e. Everyone knows that power companies charge too much.
- f. The soundness of an indirect argument depends upon whether all the possibilities have been considered.
- g. The government does not have to pay taxes to itself so it is unfair for it to compete with private business.
- h. The people are benefited because competition helps keep the cost of power low.
- i. A changed definition will produce a changed conclusion although the argument from each definition is logical.

On a preliminary tryout the results shown in the table on the following page were obtained in one excellent public school system.

On the basis of chance alone we would expect that the correct conclusion would be checked by about one-third of the pupils. But the rather close correspondence between the number of pupils who got *both statement and reason correct* and the total

number of correct responses indicates that these results were not the result of pure chance.

Class	No. of Pupils	No. of Correct Conclusions	% Correct Conclusions	Both Conclusions and Reason Correct	
				No.	%
Algebra 4	27	11	41	10	37
Algebra 4	24	7	29	6	25
Geometry 2	28	12	43	10	36
Algebra 2	24	4	17	2	8
Geometry 3	20	14	70	13	65
Math. Analysis	15	11	73	10	67

The pupils were given a chance to write in any comment or remark they wished to make. It is significant that, as a rule, those who checked the correct conclusion did not feel the need of writing in additional reasons. In several cases where they did write in additional reasons, however, these were quite to the point. For example, "If the assumption be true, there can be no other conclusion than unfairness." Another boy who got the correct conclusion said, "If the assumption which says 'It is unfair for the Federal Government to compete in private power' is true then I can conclude only that it is unfair for the government to build power lines." On the other hand, *many* students who did not check the correct conclusion wrote in additional remarks to explain their reasoning. I will quote one or two samples. One boy said, "I think that power should be in the hands of someone who can be relied upon." Another boy said, "If the rates are too high, then the government should step in, but if the rates are reasonable, let it stand. We cannot get very much for nothing." One boy who got the correct answer defended his conclusion on the grounds that "the government has unlimited power."

The item which follows calls for recognition that the issue hinges upon precise definition.

Assume the following statements are true. A young man, vacationing at a bathing beach, rented a canoe for the day. When he had paddled 500 yards offshore, the canoe upset and the young man was drowned. He held insurance covering drowning at bathing beaches. The insurance company refused to pay, claiming that he did not drown at a bathing beach.

Check the conclusion you think can best be drawn from the above event:

- 1. The insurance company should pay the claim.
- 2. We cannot decide whether the insurance company should pay the claim unless we have more information.

—3. The insurance company should not pay the claim.

Check any of the following statements you feel support your conclusion:

- a. The insurance company should pay the claim since the young man was insured against drowning at a bathing beach.
- b. The insurance company should not pay the claim since 500 yards off shore is too far to be called "at a bathing beach."
- c. The converse of a given proposition is not necessarily true.
- d. We need a clear-cut definition of "at bathing beaches."
- e. A changed definition will produce a changed conclusion although the argument from each definition is logical.
- f. The insurance company should not pay as the young man drowned as a result of the canoe upset.
- g. We need to know how much the claim was.
- h. If we accept the assumptions, this conclusion must follow.

The results of a preliminary tryout follow.

Class	No. of Pupils	Correct	
		No.	%
Algebra 4	27	5	19
Algebra 4	24	5	21
Geometry 2	28	6	21
Algebra 2	24	9	37
Geometry 3	20	2	10
Math. Analysis	15	7	47

On this item there were many comments. A large majority of the pupils felt impelled to make some sort of statement concerning their decision. I shall read two or three of the more interesting ones first. One boy says, "What kind of an agency is it if it doesn't pay when it has to? It gets the money and it should pay it out." Another says, "The insurance failed to state that it would be paid for any particular type of drowning. It merely mentioned it would be paid for *any* drowning at bathing beaches." I think that one of the most interesting comments was the following: "The company should *not* pay. The insurance says at bathing *beaches*; he only drowned at one." I regret that I am unable to tell you what this boy would say the company should do in case the unfortunate bather drowned at more than one beach. The majority of the comments, however, were directly to the point and indicated that the pupils realized that the decision hinged upon a matter of definition. The following are all taken from the responses of the mathematical analysis class:

"A clear-cut definition of 'bathing beach' is needed to draw a conclusion."

"The extent into the water of a bathing beach (by law) would have to be known."

"We would have to know how far out from a bathing beach the water is classed as being a part of the beach."

"We must know what the law accepts as a definition of a bathing beach."

"The insurance doesn't specify that the man had to be swimming but you still would have to know whether his being 500 yards offshore would entitle him to be considered at a bathing beach."

"The limit or the extent of the beach should be defined before any conclusion can be made."

"We need to know of what a bathing beach consists."

It is clear that the relatively few pupils who checked the correct conclusion really saw the point and did not check the conclusion by chance. This tends to indicate that this technique has some validity.

The third item illustrates the fallacy known as "argumentum ad hominem."

The following quotation is from a daily newspaper.

With knuckles bleeding from vehement desk pounding, Senator Glass, Democrat, today heaped a scalding attack upon Senator Nye, Republican, for calling Woodrow Wilson a liar.

Earlier, Nye spent an hour reviewing the evidence on which, as chairman of the munitions committee, he based the charge that Wilson "falsified" in testifying that he did not learn the allies had secret treaties for dividing the territorial spoils of war until after the conflict had ended.

Glass retorted: "If it were permissible in the Senate to say that any man who would asperse the integrity and veracity of Woodrow Wilson is a coward, if it were permissible to say that his charge is not only malicious but positively mendacious; that I would be glad to say here and elsewhere to any man whether he be a United States Senator or not."

"Such a charge is not only destitute of decency, but such a shocking exhibition as never has happened in the 35 years I have served in the Congress of the United States."

Check the statement below which you feel is most reasonable:

- ___1. Senator Glass proved Senator Nye's charges were false.
- ___2. Senator Glass did not prove Senator Nye's charges were false.
- ___3. Further information is needed before we can decide whether the argument is logical.

Check any of the following statements that support the conclusion you have checked:

- ___a. Senator Glass made a very effective speech in disproving the charge.
- ___b. It is a cowardly and vile thing to call a dead man a liar.
- ___c. Senator Glass calls Senator Nye a coward (and a few other names) but disproves nothing.
- ___d. This is an illustration of the logical method of disproving an argument by reducing it to an absurdity.
- ___e. No definite conclusion can be drawn from an argument which of itself reaches no definite conclusion.
- ___f. The converse of a given proposition is not necessarily true.
- ___g. Senator Glass did not state any facts which disprove Senator Nye's charges.

- h. If we accept the assumptions on which an argument is based, we must accept the conclusion also.
- i. Many words like "integrity," "veracity," "malicious," and "mendacious" need to be defined before we can decide whether Senator Glass disproved the charge.

RESULTS ON SENATOR GLASS ITEM

	No. of Pupils	No. who thought Glass disproved Nye	%
Algebra 4	27	14	52
Algebra 4	24	12	50
Geometry 2	28	15	54
Algebra 2	24	12	50
Geometry 3	20	8	40
Math. Analysis	15	0	0

As a rule, the students who thought that Senator Glass had disproved Senator Nye's charge did not feel the need of offering additional comments. On the other hand, pupils who recognized that Glass had failed to prove Nye's charges were false felt impelled to write many interesting comments. I will quote a few of them. One boy said, "Senators are paid to make laws and not to argue over the fact of another's ideals of truth." Another boy said, "He merely told Nye *indirectly* what he thought of *him* for saying what he said about Wilson." Another said, "Senator Glass very effectively, in a round about way, called Senator Nye a liar because Nye charged that Wilson falsified." One said, "Senator Glass merely called Mr. Nye a liar politely but made no point to prove that Mr. Nye was such." These comments seem to indicate that the pupils in this school system have a somewhat different standard of what constitutes "polite" repartee than the one commonly accepted in the best circles.

Some students made remarks such as the following: "Glass gave his opinion on the subject but did not prove anything." Another said, "Senator Glass did not state any facts to disprove any of Senator Nye's charges." One student said, "Anything cannot be disproved just by showing displeasure of it." One boy showed considerable political insight by making the comment, "Wilson, a Democrat. Democrats are usually hated by Republicans. That probably was the cause for it."

To summarize: on the basis of these meager data we are not justified in drawing any general conclusions. We do have some

evidence, however, that the ability to do logical reasoning as defined above is not being achieved very well by our present materials and methods of instruction. We have some definite evidence that a few pupils do reason logically and do know some of the principles of logical reasoning. All of these items can be improved in several ways.

We now face some very important questions concerning how we can teach so that *more* students will exhibit the behaviors involved in logical reasoning. Other questions arise out of the fact that we cannot tell whether the better scores made by the mathematical analysis group are a result of their previous training in mathematics, or are natural concomitants of increased maturity. The fact that the group which did best was certainly one which had a natural aptitude and interest in mathematics or some allied field may alone account for their better showing. Many similar questions need investigation.

In conclusion, recall that I have emphasized the following three points: first, the need for clarification of our objectives in terms of the behavior we hope to bring about; second, the need for evidence that we are really changing behavior; and third, the belief that if we really attack these problems we can make progress toward evaluating objectives which have usually been classified among the intangibles.

CLUB BUDGETS DISCOURAGE IMPROVIDENCE

BY J. C. BAKER

Peru, Nebraska

"Do we have money for that?" This question need no longer puzzle club sponsors and officers. Samples of the budget systems of their city, their school, and other organizations were obtained by the Calculators' Club (Junior High School mathematics) and by others of the groups allied with the Student Association.

Different types of budget procedure were analyzed and discussed at club meetings. After the sample budgets had been carefully studied, model budgets adapted to meet student-organization needs were drawn up, the result being a budget for the Student Association, also one for each of the school's diversified clubs.

Adoption of simple budgets insured that expenditures were in line with the avowed purpose of the organization and also set the students an example of thrift.

*When you change address be sure to notify Business Manager
W. F. Roecker, 3319 N. 14th Street, Milwaukee, Wis.*

COSMIC RAYS

BY T. F. WATSON

Northeastern State Teachers College, Tahlequah, Oklahoma

It has been firmly established in recent years that extremely intense and highly penetrating radiations called cosmic rays are continually pouring into the earth's atmosphere from outside space. Experimental evidence indicates that these radiations originate in inter-stellar space so that the name is well chosen. These rays were first discovered in 1900 when C. T. R. Wilson found that the air is always slightly ionized so that a well insulated electroscope is slowly discharged. It was at first supposed that the radiation was due to radio-active materials present in the earth's crust, but when the Swiss physicist Gockel¹ in 1910 took an electroscope up in a balloon to a height of 4500 meters and found that the rate of discharge was considerably greater than at the earth's surface, he established that they originate either in the upper atmosphere or in the regions beyond our atmosphere.

Seeking knowledge of cosmic rays scientists have gone wherever man can go; to the tropics and to polar regions, to the mountain tops and into deep mines, into the stratosphere and deep underneath the surface of bodies of water, making careful and painstaking observations which had been carefully planned to obtain information concerning the nature of these mysterious radiations. It was at first thought that the sun might be their source, but as early as 1911 Hess found that they were apparently as intense at night as during the day. Subsequent investigation revealed that the rays come from all over the celestial dome and that they are quite as intense when the Milky Way is out of sight as when it is overhead; indicating that they originate outside our galaxy. The absence of any observable effect of the sun and stars on the intensity of cosmic rays indicates that the radiation does not come from these bodies but from inter-stellar space.

ENERGY OF COSMIC RAYS

To obtain information concerning the energy of cosmic rays, accurate measurements of the absorption coefficients of various materials for these rays have been made. Millikan and Cam-

¹ Gockel, *Phys. Zeit.*, XI (1910), 280.

eron,² using a type of electroscope which had been made more sensitive by filling it with gas at several atmospheres pressure, measured the degree of ionization produced by these rays after they had penetrated to various depths in snow-fed mountain lakes. Regener³ continued this work and found that some constituents of cosmic rays are able to penetrate more than 230 meters of water. This means that some of the rays have sufficient energy to penetrate 20 feet of lead. Millikan and Cameron found that the radiations are not homogeneous but that they consist of at least three distinct energy groups of widely different penetrating power.

The study of variation of cosmic ray intensity with altitude which was begun by Gockel in 1910 has been extended by Hess, Kolhorster, Millikan and Regener, Piccard, and others.⁴ Intensity measurements have been extended to a height of 17 miles by means of self registering electroscopes sent up in unmanned balloons. From a curve showing the intensity of cosmic radiation as a function of height the effective absorption coefficient in air at any altitude has been determined and thus an estimate of the hardness and intensity of the rays before they enter the earth's atmosphere is available.

Millikan⁵ estimates that the energy coming to the earth in the form of cosmic rays is approximately one-half of the total energy coming to the earth in the form of radiant heat and light, and since the energy per cubic centimeter in the form of light and heat inside our galaxy must be much greater than in inter-galactic space while the cosmic ray energy is probably just as dense outside as inside our galaxy, it follows that there is in the universe much more energy in the form of cosmic rays than in the form of heat and light. From the astronomical estimates of the distribution of the nebulae, Millikan concludes that the total radiant energy in the universe existing in the form of cosmic rays is from 30 to 300 times as great as that existing in all other forms of radiant energy combined.

NATURE OF COSMIC RAYS

The energy brought to the earth in the form of cosmic rays undoubtedly consists, when it enters the earth's atmospheres, of either electromagnetic waves or charged particles or pos-

² Millikan and Cameron, *Phys. Rev.*, XXVIII (1926), 851.

³ Regener, *Phys. Zeit.*, XXXIV (1933), 306.

⁴ Millikan, *History of Research on Cosmic Rays*, Nature CXXVII (1930), 14.

⁵ Millikan, *Electrons (+ and -), Cosmic Rays* (1935), 309.

sibly both. Regardless of the constitution of these primary rays, the radiation when it reaches the earth's surface must be made up of a mixture of photons and charged particles, due to the interaction of the primary radiation with the atoms and molecules of the atmosphere.

An ingenious apparatus developed by C. T. R. Wilson and known as the Wilson cloud chamber has been very useful in studying all kinds of ionizing radiations and particularly in studying the constitution of cosmic radiation. The Wilson cloud chamber consists of a chamber in which super-saturation is produced by sudden expansion and a resulting sudden drop in temperature of the gas in the chamber. Under these conditions gaseous ions serve as nuclei for the formation of water drops and the path of an ionizing radiation can be traced through the chamber by photographing the water drops formed on the ions. By using Wilson cloud chambers in very strong magnetic fields it has been established that the immediate agents responsible for the most cosmic ray ionization at the earth's surface are charged particles—protons, electrons, and possibly positrons. Energy considerations, however, indicate that these are not the primary radiations but are secondary radiations resulting from interactions of the primary rays with the matter of the earth's atmosphere or with the material in the walls of the cloud chamber.

If the primary cosmic radiation, as it comes into the earth's atmosphere, is made up of electrically charged particles rather than photons, these particles should be deflected towards the earth's magnetic poles by the magnetic field of the earth. Recent investigation by A. H. Compton,⁶ Millikan and Neher,⁷ and others indicate that such an effect exists. Millikan and Neher found a decrease of about 8 per cent in intensity between Los Angeles and a point on the magnetic equator directly south. A. H. Compton found a slightly larger effect. This latitude effect indicates definitely that a part of the cosmic rays are charged particles and calculations by W. F. G. Swann⁸ on the basis of this effect show that at least 31 per cent of the primary cosmic radiation consists of charged particles. In a recent symposium on cosmic rays Millikan, Compton, and Swann

⁶ A. H. Compton, *Phys. Rev.*, XLIII (1933), 387.

⁷ Millikan and Neher, *Phys. Rev.*, XLVII (1935), 205.

⁸ Swann, *Phys. Rev.*, XLVIII (1935), 641.

agreed that the experimental evidence indicates that the primary rays are a mixture of electromagnetic waves and particles.

ORIGIN OF COSMIC RAYS

Scientists are puzzled to account for the tremendous energies associated with the primary cosmic rays. No natural phenomenon has ever been directly observed which released energy in quanta anywhere near the amount possessed by a primary cosmic ray particle or photon.

The only possible source of these observed energies, at least the only plausible one suggested by scientists up to the present time, is the conversion of mass into energy. Conversion of mass into energy was first suggested by the astronomers because they could see no other possible way to account for the enormous quantities of heat radiation that have been pouring out from the stars in the billions of years during which the stars are supposed to have been in existence. In 1905 Einstein deduced, as one of the most important consequences of his special theory of relativity the important relation between the mass and energy involved in such conversion, namely, that for each gram of matter converted 9×10^{20} ergs of energy result.

R. A. Millikan thinks that the cosmic ray energies result from the building up of the more complex atoms of matter from hydrogen. For example, if an atom of helium is built up of four atoms of hydrogen, .031 atomic units of mass, the difference between the atomic weight of four atoms of hydrogen and one atom of helium, are left over. This is equivalent to about 4.63×10^{-5} ergs of energy, an amount which is at least comparable with the energies possessed by some of the cosmic rays. On the basis of this theory larger amounts of energy would be expected to be liberated when the heavier atoms are built up from hydrogen, but some of the cosmic rays have been found to have energies in excess of that which would result by the formation from hydrogen atoms of an atom of the heaviest known element.

Sir James Jeans has developed a theory which accounts for the energies of the cosmic rays by assuming that electrons and protons fall together in inter-stellar space and mutually annihilate each other, the entire mass being converted into energy. The annihilation of this amount of mass would result in energies of about .0015 ergs or about a billion electron-volts.

which is of the right order of magnitude for the higher energy group of cosmic rays.

The question of the source of energy of cosmic rays is still a matter of speculation. Both of the foregoing hypotheses seem unreasonable because of the extremely low density of matter thought to be present in inter-stellar space. At present, it is best to defer judgment as to the origin of the rays, but we may feel certain that the information gained by their study will ultimately prove extremely important to our understanding of astrophysical phenomena.

A PROJECT IN THE STUDY OF VOLCANOES

BY CATHERINE HEARN¹

Teachers College of Connecticut, New Britain, Connecticut

Significant Idea—The earth's surface is continually changing.

Specific Objective—Volcanoes help to change the earth's surface.

A volcano at birth is not a mountain. It is only a shaft between the earth's surface and subterranean molten rock. The eruptions may cause a mountain or a plain. If a mountain is formed it is generally built in the shape of a cone. The hollow at the top is the crater. The hot rock which comes out of the inside of the cone may come out in a liquid form called lava, or it may be thrown out in solid pieces.

In a quiet eruption the lava rises in the crater and overflows the rim. This results in what is called a lava dome. In the explosive eruptions rumblings may be heard for many weeks before the eruption. When the explosions become violent, dust and pieces of rock are shot out of the crater and fall to the sides of the cone. The material erupted is called "tuff" or "cinder," and the volcano is described as a "cinder cone."

Explosive volcanic eruptions are caused by the expansion of water vapor and other gases which are dissolved under pressure in the molten rock material (magma) beneath the earth's crust. As this material rises to the surface the resulting lessening of the pressure allows these gases to escape, sometimes with explosive violence.

¹ Senior in the Elementary Department under the Supervision of O. E. Underhill, Instructor in Physical Science.

W. W. Hobbs in "Earth's Features and Their Meanings"² describes how to construct a miniature volcano model to show how a cinder cone is made. In this apparatus first white then colored sand is sent up in a light current of compressed air supplied from a tank. The alternating layers of sand form from the various eruptions.

A modification of this apparatus, which is very simple and may be constructed in the average schoolroom, was made. (Fig. 1.) A circular piece of wood about 15 inches in diameter was se-

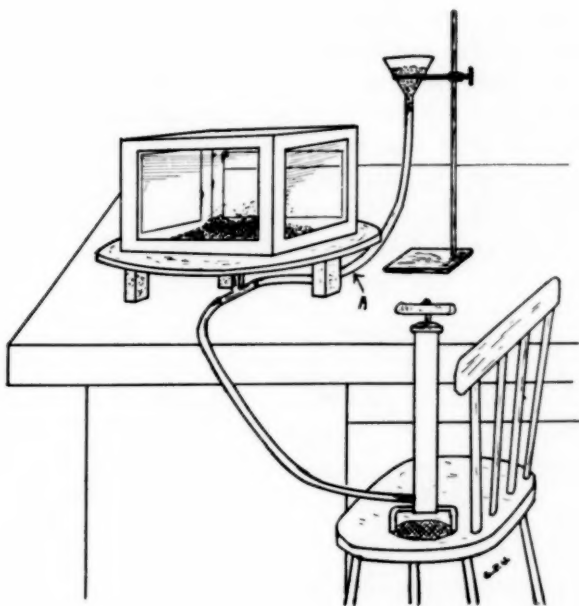


FIG. 1

cured and a hole drilled in the center. This was supported on three bricks standing upright. A glass T-shaped tube was inserted through the hole and a piece of rubber tubing was attached to each of the other two ends of the tube. At the end of one piece of tubing was a funnel. Bird gravel dyed with Sunset Dyes³ (red, blue, and black) was used. At first the breath was used as the source of air supply but the T-shaped tube soon filled with so much moisture that the gravel became too moist

² Hobbs, W. H. *Earth's Features and Their Meanings*. Macmillan Company, 1931. ill. 119, page 122.

³ Mix the dye with a little water, add the gravel and let it boil for fifteen minutes. Pour off the dye and spread the gravel on paper in the sun to dry.

to pass through the tube. An automobile tire pump was then used to force the air and gravel through the tube. After many attempts at regulating the amount of air the gravel came through the tube in a steady flow. The force of the air was so great that the gravel tended to bounce off the board on which it was supposed to fall. To remedy this holes were cut in a hat-box and covered with cellophane for windows and the box was placed on the board. When the gravel hit the top of the box it was thrown back onto the board thus gradually building up the cone of the volcano. First a layer of white gravel was made, then one of red, next came another one of white, then black, and finally the last was white.

When the cone was high enough to see the formation a piece of glass was carefully pushed down through the center and the gravel cleared from one side. The different layers of gravel, which represented the eruptions at different times, were then clearly seen. (Fig. 2.) In the actual formation of such a cinder cone many years may elapse between each eruption.

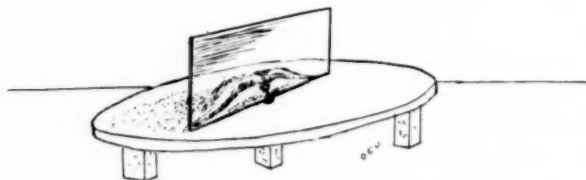


FIG. 2

In the classroom the children may take turns at the pump and at pouring the gravel into the funnel. Three people are needed to carry on the project. One person must pump the air into the tube with short, quick strokes, a second person must keep the reservoir filled with gravel and a third person must constantly jar the rubber tubing at "A" (Fig. 1) in order to prevent the gravel from jamming. With a little practice a rather realistic imitation of a volcanic eruption will result. As the cone is built higher the realism is increased, as the entering gravel has to force its way through that which falls back into the crater.

Another very realistic imitation of volcanic eruption may be produced by filling a crucible with powdered ammonium dichromate and igniting it by a match head imbedded in the di-

chromate⁴ (Fig. 3). The combustion results in the formation of chromic oxide in a rather porous or crumb-like form, which occupies many times the volume of the original dichromate. The nitrogen gas formed by the reaction forces this material

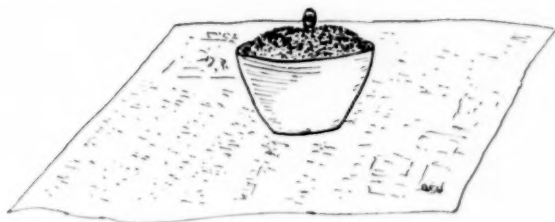


FIG. 3

into the air and as it falls it builds up a cinder cone type of structure. As the combustion proceeds the gas forming in the interior of the mass pushes its way up through the chromic oxide which has previously been formed, and sprays out a miniature shower of "volcanic dust" and sparks.

⁴ Stone Charles E. Some Supplementary Chemical Experiments. SCHOOL SCI. AND MATH., Vol. XXXIV, Dec. 1934, p. 924.

METALS RIVAL HUMANS IN BEING INFLUENCED BY UNFAVORABLE ENVIRONMENT

Some of the almost human characteristics of metals—susceptibility to environment, resistance increased by inoculation, bathing, mating, and long life—were described at the opening of the symposium on corrosion-resistant metals before the American Society of Mechanical Engineers.

A metal and the environment in which it has to live must be mated so as to live together peaceably, or at least until the owner gets a reasonable return on his investment, declared Dr. F. N. Speller of the department of metallurgy and research of the National Tube Company, Pittsburgh, Pa., in his introductory remarks.

"It should be remembered," he explained, "that metals are, in a way, quite like human beings; although they are susceptible to unfavorable environment, their resistance can be built up by inoculating them with alloying elements and by keeping their surfaces reasonably clean and free from foreign deposits."

Pointing out that one single metal can hardly be the final solution to corrosion under the myriad of existing conditions, Dr. Speller emphasized that the problem for the engineer is to select a metal that will best serve any specific purpose at the lowest ultimate cost. Too often first cost is the determining factor, he declared.

Nickel, stainless steel, cast iron, zinc, lead and aluminum shared the spotlight in the corrosion symposium.

LOOKING UP THE RHODE ISLAND TREE OF NATURE LEADERSHIP

BY WILLIAM GOULD VINAL
National Recreation Association

A Tercentenary stimulates us to peer into the past. The Rhode Island Tree of Nature Leadership has made a notable growth in a fertile environment. Its roots penetrate deeper than the three centuries. They go back to the red man and the freedom of the wilderness.

William Blackstone (1595-1675) planted the first apple orchard to bear fruit in Rhode Island. It is said that "he had the first of that sort called yellow sweetings that were ever in the world perhaps, the richest and most delicious apple of the whole kind." In 1830 three of his trees were still living and two of them bore apples. The Rhode Island Greening after the test of over three hundred years is still rated as delicious. Early Rhode Islanders had scanty time to study natural history in the way of scientific inquiry. Their mental energy was spent on theological controversy.

It may have been that same urge that is reported to date back to the Garden of Eden that made "rattlesnake day" one of the early calendar events of the colony. It was an occasion which all the inhabitants observed by making an annual pilgrimage to Snake Den Ledge in the northern part of Johnson to kill snakes.

In the meantime the little Williamses dug clams and oysters near what is Market Square. Capitol Hill was covered with pine according to the diary of the Browns, who went duck hunting along the cove back of Union Station. The log cabins along North Main Street were made from the materials of the environment even to the thatch on the roofs. The home lots extended from the main street to the Highway, now Hope Street. In the vicinity of Benefit Street on the steep hillside were the orchards. The curve in Weybosset was an Indian Trail which led from hummock to hummock where the Narragansetts crossed the marsh to College Hill. At the Falls of the Moshassuck was Smith's Grist Mill (1646). It was here that the boys drove the cattle to water evidently being somewhat boisterous as the Assembly felt called upon to order quiet (1681). The struggle for existence by the early settlers for food, shelter, raiment, and

medicine was essentially first-hand nature study. The Assembly could scarcely predict that the coming of civilization would make the Moshassuck a channel of scum and typhoid. They were concerned with what to them were more momentous questions.

With the founding of Brown University (1764) Natural History began to take on more definite form. The American Revolution had caused a break in the college exercises. In 1782 after the departure of the French from University Hall which they had used as a hospital and barracks the state repaired the hall and the college reopened in October, 1783. The educational method at Brown in those days, as was true in other colleges, was based on the textbook.

In the autumn of 1782 Doctor Waterhouse was elected a fellow of Rhode Island College (Brown University) and in 1784 was appointed Professor of Natural History, beginning without salary. In 1785 one of the first courses opened to the public was further unusual in that it had no textbook and no examination. The subject of natural history was given by Doctor Benjamin Waterhouse in the old state house. Doctor Waterhouse as Professor of Natural History was one of the earliest teachers of natural history in America. Waterhouse was a companion of Gilbert Stuart. They hired a "strong-muscled blacksmith" as a model for drawing from life. Waterhouse was also acquainted with Dr. Fothergill and William Curtis who had botanic gardens near London. Judge Staples writing in 1841 made favorable comment by saying that "by the lecture system the amount of knowledge acquired this way is not so great or valuable, or so lasting as that acquired by the old-fashioned mode of thought and personal study."

Doctor Waterhouse aimed "to excite and direct curiosity to books" rather than to nature. Some of the headings of his lectures are both interesting and curious.

IX. On the Grand Principle of Agriculture.

X. The Linnaean System of Botany, briefly explained. The peculiar laws of nature on which this sexual system is founded. Of Sir Thomas Middleton, Grew and Linnaeus.

XIV. On the Relative Perfection or Scale of Beings. 1st. Inorganized Beings; 2d. Organized and Inanimate Beings; 3d. Organized and Animate Beings; 4th. Organized, Animate and Reasonable Beings.

XV. Man: placed at the top of the cone; or visible series of creation.

Doctor Waterhouse was appointed Professor of Theory and Practice of Medicine in Harvard Medical School where he remained until 1812. James Russell Lowell described him as wearing "Amazing spectacles . . . rising like two moons at once. The great collar, disallowing any independent rotation of the head. I remember he used to turn his whole person in order to bring their foci to bear upon any object. One can fancy that terrified Nature would have yielded up her secrets at once, without cross-examination, at their first glare." Doctor Holmes said that he was "a brisk, dapper old gentleman, with hair tied in a ribbon behind, and I think powdered . . . the good people of Cambridge listened to his learned talk when they were well, and sent for one of the other two doctors when they were sick."

It may help our orientation if we realize that it was after Doctor Waterhouse left Rhode Island that the constitution was adopted by the thirteen states (1789) and that Rhode Island became a state (1790). Political discussions in those days were perhaps as vigorous, as uncandid, and as unscientific as one hundred and fifty years afterward.

Doctor Solomon Drowne (1753-1834) was "a great admirer of the works of nature, a distinguished Botanist, a sincere patriot, and an honest man." The Rhode Island Historical Society has his "Journal of a Cruise" in the Fall of 1780. In 1811 Doctor Drowne was appointed Professor of *Materia Medica* and Botany in Brown University. In 1813 he delivered a course of Botanical lectures in the summer to the students of Brown University and to a class of the citizens of Providence. After he became a professor he endeavored to found a botanic garden and said that "The establishment of a Botanic Garden as a repository of the native plants of this country and as subservient to the purposes of medicine, agriculture, and the arts, is doubtless an object of great importance."

John Whipple Potter Jenks (born 1819) developed a taste for natural history while attending a log school in Charlotte County, Virginia, often hunting foxes and boars. He entered Brown at sixteen vigorous in health but poor in purse. He worked in the garden of President Wayland and boarded himself at fifty cents a week. He was principal of Peirce Academy in Middleboro, Massachusetts, for thirty-three years (until 1871).

It was while in Middleboro that Professor Jenks rendered im-

portant service to Louis Agassiz in preparation of his treatise on the embryology of the turtle, a service which Agassiz acknowledged in the preface of his book. "Turtle Eggs for Agassiz" is the title of a literary production by Dallas Lore Sharp and reappears in the fiftieth anniversary edition of the *Atlantic Monthly*. This classic should be read by every embryo naturalist.

In 1871 Professor Jenks was called to Brown University. He collected for the Museum of Natural History which was located in Rhode Island Hall. He could not bring himself to the point of including apes and monkeys in his anthropological collections. He was regarded as a popular lecturer and should go down in biological history as a collector.

At the age of 55 Professor Jenks camped for 50 days in the Everglades of Florida (1874), "to the naturalist a perfect elysium." His diary "Hunting in Florida" is descriptive and interesting reading. "Found it almost impossible to secure a single bird we had shot, a half dozen (Alligators) at a time springing from their lurking-places the moment the bird touched the water." He did find the alligators useful when traveling camp-ward and hitched his boat hook over the shoulder of the beasts who would often tow him in the right direction. His campmates one time went on an expedition, "Thus leaving me alone at the camp for the night. . . . I had become accustomed to our nightly serenade medley of alligator bellowing, wild cat yawling, frog peeping, turkey gobbling, heron screaming, owl hooting and every other kind of unearthly sound pertaining to a wilderness swamp." In arriving on terra firma his scow became a wagon body. In his collections were spoonbills, egrets, ibises, and snake birds.

Perhaps the next popularizer of natural science in the Providence Plantations was Alpheus Spring Packard (1839-1905). His three years of graduate study with Louis Agassiz (1861-1905) gave him a professional relationship to Humboldt, Cuvier, and Lamarck. In 1867 and for 20 years he was editor-in-chief of the *American Naturalist*, "A popular scientific monthly . . . to meet the wants of all lovers of nature." In 1873 he again worked with Agassiz as a teacher in the Anderson School of Natural History at Penikese. From 1875 to 1878 with E. S. Morse and J. S. Kingsley he established a Summer School of Biology at Salem under the auspices of the Peabody Academy. These were the forerunners of the Marine Biological Lab-

oratory at Woods Hole and the Summer Nature Schools of today. Packard wrote about glaciers, geology, embryology, and insects. When he came to Brown in 1878 as Professor of Zoology and Geology he brought the spirit of Agassiz who said "Study nature, not books." As Agassiz would stop and hobnob about nature with the men in the fish market so Packard was interested in the weavers in the mills at Valley Falls. They were both generalists, popularizers, and with a regard for the amateur.

Henry G. Russell probably builded better than he knew when he started the scientific management of trees at Potowomut Neck in 1874. He also was brought under the Harvard influence through friendship with Charles Sprague Sargent. Russell worked out his own methods at a time when there were no books to guide him. His trees were planted in rows. The 560 acre estate was bequeathed to Robert H. I. Goddard in 1909. In 1910 the American Forestry Company set out 150,000 trees. The area became one of the best examples of scientific forestry in the United States and was the source of many photographs to show the possibilities of capable management.

If Packard was the last general naturalist with leanings toward zoology Bailey was the last general naturalist with inclination toward botany. William Whitman Bailey (1843-1914) was not merely a botanist. He was a chemist, zoologist, botanist, geologist, poet, editor, and alpinist. For nearly fifty years he contributed to the *Providence Journal*. All of these interests may be accounted for by a study of his early influences. His father was Professor of Chemistry, Mineralogy, and Geology at the U. S. Military Academy at West Point. At Harvard he studied with Asa Gray. His brother graduated from Harvard in 1859 and was professor of Natural Science in the University of New Brunswick. William Whitman Bailey was appointed Professor of Botany at Brown in 1881, just three years after the coming of Packard. Upon his passing in 1914 Dr. Faunce said: "A genuine lover of nature, he roamed through the woods and fields gathering plants and flowers and fruits with the appreciation of a poet as well as the enthusiasm of a scientist."

The period now arrives when Rhode Island nature study is beginning to take form unto itself. Without Agassiz there could have been no Jenks and Packard. Without Gray there could have been no Whitman Bailey. Without Jenks, Packard and Bailey there could have been no Bumpus and without Bumpus

there could have been no Dallas Lore Sharp. Nature study is a growth. It is to these men that we must look for the intellectual ancestors of the nature study movement of today. For this reason we should keep record of the traditions that we have inherited. Upon the foundations which these early naturalists laid the nature movement of today has been built.

Hermon Carey Bumpus (1862) is both teacher and scientist. His service extends to museums, national parks, and universities. His native ability traces back to his ancestral tree and his enthusiasm and faithfulness to science may have been influenced by his pedagogical forebears. Bumpus entered Brown as a freshman in 1880, he was a teacher of biology there in 1890-1901, and is now a member of the Board of Fellows. His thesis was on the American Lobster. While Director of the American Museum of Natural History that institution was first taken to the children of the great metropolis. It was in the early nineties, under the regime of Doctor Bumpus, that extension classes in laboratory work were started with the distinct idea of preparing teachers for science in the elementary grades. The 24 trailside museums in the country, especially those in the national parks, are largely due to his efforts.

Although Dallas Lore Sharp (1870-1929) cannot be listed as a Rhode Islander, he received his education at Brown and a story of nature leaders in New England is not complete without mention of his influence. Sharp was a literary genius who knew nature as did John Burroughs. An idea of his style can be gathered from the way he talked to one of his classes in literature at Boston University. "You are the most fascinating enigma I've ever faced. It staggers me to think what possibilities lie fallow in these lecture rooms, what seeds of achievement await here, ready to sprout. Next to watching my four boys grow, or trying to outguess the woodchuck on Mullein Hill, there's nothing like you. No. Nothing half so mysterious and thrilling." Sharp got fun out of life and shared it.

I once heard Professor Sharp give a tirade to the effect that he was asked to study the eyeball of a flea in the biological laboratory. "No siree, he would not stay around to do that." From such poetic license, shall we call it, arose the rumor that he was put out of the department. To a query on the point Doctor Bumpus quickly replied, "Not at all." Sharp was not interested in marks, grades, committee meetings, or faculty meetings. He had a sincere interest in the simple life which

enabled him to write such classics as *Watchers in the Woods*, *Lay of the Land*, and *Hills of Hingham*.

The following unpublished anecdote about Sharp was told me by Doctor Bumpus: Sharp had considerable difficulty in financing his student days. He slept at Rhode Island Hall which housed Jenks' museum and the biological laboratories. Sharp and Warmesley shared a long, narrow bed in which they finally put a board lengthwise and in the middle. At Woods Hole the time was approaching when garden spiders were to be used in a class of 130 students. Bumpus advertised that he would purchase garden spiders at one cent each but none appeared. He then raised the price to two cents and still only obtained a few. One day Sharp inquired as to the market price on spiders to which Bumpus quickly replied, "Five cents." It appeared that Sharp had several glass jars of garden spiders but was waiting for the market to go up.

Doctor Albert D. Mead, the vice-president of the University, is still claimed by the biologists. His pedagogical tree goes back to Agassiz through Professor Whitman of the University of Chicago. The writer thinks of Mead as the artist-naturalist. Agassiz expressed himself with chalk, Sharp through description, but Mead used clay. His deft way of helping the student to visualize the three dimensions of the embryo through the manipulation of clay was an effective method that other lecturers would do well to simulate. Doctor Mead, like his predecessors, is also a man of the community. His notable experiments in lobster culture began in 1900 at a floating laboratory located at Wickford, Rhode Island. Young lobsters during their stages of moulting fall easy prey to fish and even their own brethren. Doctor Mead figured that success in rearing lobsters would be enhanced if the fry was kept in motion for their three weeks of swimming life at the end of which they settle on the bottom and crawl. A stirring apparatus proved efficient in protecting the young during this critical period. Doctor Mead's humor is always refreshing. At the presentation of the portrait of Doctor Bumpus to the University on June 15, 1927 Doctor Mead referred to the young artist Howard E. Smith as "Executioner" whom he said had established a record, "except Morpheus, by keeping Dr. Bumpus quiet for two consecutive hours without anesthetics." "If I may paraphrase the words of my remote and classical predecessor—we are come to hang Caesar, not to praise him; and so, with our tribute of affection and es-

teem unspoken, we hand over his shadow to the Director of Ceremonies."

Professor Frederick Gorham extended his influence to such public measures as mosquito control, sewerage disposal, and public health. Doctor Herbert Eugene Walter stands out as the one who uses ingenious devices and phrases to drive a thought home. His books on eugenics and on comparative anatomy abound with original ideas. The writer remembers best of all his early morning bird walks given for those interested without credit or examination, or unlike a well known railroad they were not subject to change without notice—the trips being held, rain or shine.

I am not alarmed that the generalists such as Agassiz, Jenks, Packard and Bailey or the masters such as Bumpus, Mead, Gorham and Walter have given place to bacteriologists, physiological chemists, pathologists and petrologists. It is true that specialists should be cautious not to narrow their sympathies along with their thoughts. There is still a place for courses in natural history for the non-technocrats of the future—college men who go into other walks of life. Biologists, as custodians of biology, are themselves responsible for such unfortunate debacles as the Scopes Trial. The diffusion of scientific knowledge cannot filter down from any other source but its origin. As President Washington said in his farewell address, "In proportion as the structure of a government gives force to public opinions it should be enlightened."

A second trunk that grows on the Rhode Island Tree of Nature Leadership is the contribution from the field of education. These roots lead back to Comenius (1592–1670), Rousseau (1712–1779), Pestalozzi (1746–1826) and Froebel (1782–1852). The educational lineage is just as notable as the scientific.

Henry Barnard (born 1811) was the son of a Connecticut farmer. His early training consisted of doing chores plus the three R's of the District School. It was not until he entered Monsen Academy, Northampton, Massachusetts, that he was awakened to the beauties of the outdoors. After graduating from Yale (1830) he had opportunity to travel in Europe where he visited Pestalozzian schools. In 1843 he came to Rhode Island to reorganize the public schools of the state. In 1854 he represented the United States at an International Educational Congress held in London. On this trip he gained ideas about Froebel's Kindergarten. The next year he began his twenty-six

years as editor of *The American Journal of Education* which Doctor Frank P. Graves, New York State Commissioner of Education, characterizes as "the greatest possible contribution" to education.

It is in this valuable work (Vol. XVI (1866), p. 258) that is found a report by Professor S. S. Green of Providence, for a committee appointed by the National Teachers' Association in 1864. Professor Green asks, "Would you know . . . a good teacher? . . . Let him have ears of corn, pine cones, shells, and as many other objects as he chooses to collect, and then require him to give lessons in reading, spelling, arithmetic, geography, and the English language . . . If they love to talk of what they do at school . . . then employ him . . . You are sure of a good school." It is evident that the foremost educators in Rhode Island at this time were thinking of the "object lesson" which was the beginning of emancipation from the textbook.

Doctor Walter E. Ranger was born (1855) on a New England farm. He earned his way through Bates College by teaching common schools in the winter term. His thirty years as the Commissioner of Education (1905-1935) for the State of Rhode Island offers many instances of his fostering care for nature education. The state Arbor Day Booklets have been published continuously since 1886 and his annual messages are exemplifications of his nature philosophy. In the booklet for April 15, 1907 Theodore Roosevelt, the naturalist president, wrote a message to the school children of Rhode Island. In 1917 the Commissioner of Public Schools had published "Nature Study by Grades," a course prepared for the public schools of the state.

David W. Hoyt (born 1833) came to Providence in 1863. For over fifty years he was a teacher and principal in the Providence high schools. He came to Brown when there were only four buildings on the campus (1855). Following his graduation he was Professor of Natural Science at Polytechnic College in Pennsylvania one year and at the New Hampton Institute, Vermont, four years. He was president of the Providence Franklin Society 1887-88. He always had a close interest in local natural history often tramping thirty miles to collect data. Perhaps his most important natural history paper was "The Influence of Physical Features upon the History of Rhode Island" which was published by the State Department of Education.

Mr. Isaac O. Winslow was elected superintendent of the

Providence Public Schools, April 25, 1913. As was the case of Randall J. Congdon before him he served on a Nature Study Committee. His book on "The Principles of Agriculture" shows his interest as well as familiarity with the subject. The private schools also showed interest in nature study. Moses Brown had shown a fondness for natural science and at the school named for him Thomas Batty for many years led the boys in interest in the open.

The present Rhode Island Normal School was established in 1871 and in 1920 became the Rhode Island College of Education. In "general exercises" Dana P. Colburn (1823-1859) threw aside the textbook and often discussed with the assembly of students such questions as natural philosophy. He led the pupils by skillful questioning to discover for themselves. By exhibiting objects he would impress a lively picture on their imagination. His forte was arithmetic. In the fall of 1853 Professor Guyot gave lectures on Physical Geography.

Perhaps the most noted of a long line of nature teachers at the Rhode Island Normal was Mary Cynthia Dickerson (1866-1923). As a girl she had home duties and found recreation in flowers and small animals. She worked her way through the University of Michigan and the University of Chicago. She spent several summers at Woods Hole and once assisted David Starr Jordan at Stanford. At the Rhode Island Normal School (1897-1905) she laid the foundation which enabled her to construct groups at the American Museum of Natural History (1908-1921). It was in Rhode Island that she also gathered data for her "Frog Book" (1906) and for her "Moths and Butterflies" (1901). Her artistic nature is shown in the photographs used for these books and her "Frog Book" is still the outstanding beddecka to which every naturalist turns for frog art and knowledge. Miss Dickerson was easily accessible to the man of the street. She had indomitable energy and burned the midnight oil when working on nature interests. Her books are scientifically correct with the added charm of interest and beauty.

Nature leadership for teachers at the Rhode Island College of Education has been faithfully carried on since 1910 by Doctor Marion Dodge Weston.

The Roger Williams Park Museum started as an Art Museum and then became a Museum of Natural History in 1903. It began work in the Public Schools in 1914-15 under the enthusiastic direction of Harold Madison, director. A schedule

was worked out with the school department whereby the sixth grades of the city visited the museum twice a year. The natural history circulars published by the Park Museum have created a great deal of interest throughout the nation. The museum also has several notable collections. The Manly-Hardy collection of North American Birds is the result of 66 years of effort and has some species which have ceased to exist. The Horace Carpenter collection of shells (2700 species) and minerals (450 kinds) represents 50 years of work. Among the minerals there are 250 chemically manufactured minerals made by Mr. Carpenter. The museum has a complete mammal collection to the last panther killed in Rhode Island. Each collection, of which these are representative, has been made by an expert who is authoritative and highly respected in the city. At the present writing this well-known institution is under the stewardship of Doctor Bryant who came here from the Buffalo Museum.

Henry E. Childs is the liaison officer between the museum and the public schools. Formerly instructor in biology at the Technical High School perhaps he was best known for his weekly articles in the *Sunday Journal* on Nature Study. June 30, 1929 he was appointed "Instructor of Nature Study and Visual Education." His department is growing rapidly and by June 1936 will again move to larger quarters.

Providence is the home of many natural history societies. The Rhode Island Society of Natural History was organized in 1837. According to its records, on file in the R. I. Historical Society, it held a course of lectures. The Providence Franklin Society was an old society which gave birth to many branch societies such as the Providence Engineering Society and the Horticultural Society. The R. I. Audubon Society has done notable work in bird education. The R. I. Field Naturalist Club has held field trips every week for a period of thirty years. These clubs represent for the most part a period of exploration and descriptive natural history. Doctor Henry P. Lovewell collected some 300 native Rhode Island Medicinal Plants. He found Bennett's *Flora of Rhode Island* a decided help. Martin Bowe has a beetles who's who in Rhode Island. Doctor Edwin E. Calder limited his collecting to tiger beetles and gave lectures on "Hunting Rhode Island Tigers." In a college town such as Providence there are always enough people interested in particular niches of science who are ready to start a club.

Lord Bacon once wrote that "A private man may sow the

seeds of science, but public benefaction must water them." The Rhode Island State College was founded at Kingston in 1888. The Experiment Station was established the same year. Professor Steene organized the Nature Guard which was a forerunner of the State 4H Clubs which have done so much to interest the country boy and girl in nature.

The leaven of nature study has been long at work in Rhode Island. Professor Hanor Webb one time plotted the geographical distribution of noted naturalists. His map showed that these men were more numerous toward the Atlantic seaboard. If I were to guess I would estimate that there are 500 laymen to one naturalist in Washington, 5000 to one in Providence, and 10,000 to one in the Kentucky mountains. The accumulated nature impacts in Providence are comparatively high. As in most places the general public is vague as to the existence of such a movement and scientists themselves, ever more specialized, have a very rudimentary conception of the complete picture. Agassiz once remarked that "there is a world of meaning hidden under our zoological and botanical nomenclature, known only to those who are intimately acquainted with the annals of scientific life in its social as well as its professional aspect." This brief epitome of Rhode Island nature leadership might well be enlarged upon by some research student in education. With the increase of leisure time activities nature recreation may be looked to as a future development.

WE STAND CORRECTED

In a note at the bottom of page 29 in the Jan., 1937 number you say that Wheeler Dam, the newly completed T.V.A. project near Florence, Ala., is named for Gen. John Wheeler. I think you will find that General Joseph Wheeler was the correct name. Gen. Wheeler known as "Fighting Joe" served both in the Civil and Spanish-American war and served his district several years as a member of Congress. The old Wheeler home stand now near Wheeler Station, Lawrence County, Ala., not far from Wheeler Dam.

As chemistry and mathematics teacher in a Junior College, I find much use and great interest in SCHOOL SCIENCE AND MATHEMATICS.

REYNOLD Q. SHOTTS,
Rabun Gap, Ga.

Science ever has been, and ever must be, the safeguard of religion.—
Brewster.

GEOMETRICAL REPRESENTATIONS OF THE TERMS OF CERTAIN SERIES AND THEIR SUMS

BY ADRIAN STRUYK

Clifton High School, Clifton, New Jersey

Certain elementary theorems on the summation of simple arithmetical series can be illustrated in a manner analogous to that used for the algebraic identity $a^2 + 2ab + b^2 = (a + b)^2$. The illustrations show how geometric figures which represent the terms of one member of an equation can be assembled to form a geometric figure which represents the other member.

The basis of these illustrations is the representation of the number 1 by a cube. Any integer N may then be represented by a figure having integral dimensions and a volume equivalent to N unit cubes. The representations of the integers N , $2N-1$, MN , and N^2 given in figure 1 are obvious.

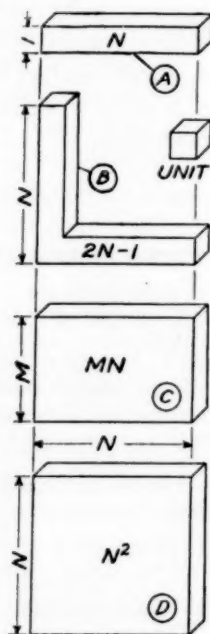


FIG. 1

We proceed to the illustrations of the following theorems:

(I) $1+2+3+\cdots+N=\frac{1}{2}N(N+1)$. See figure 2.

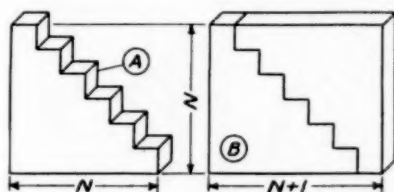


FIG. 2

(II) $1+3+5+\cdots+(2N-1)=N^2$. See figure 3.

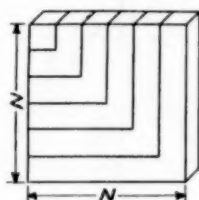


FIG. 3

(III) $1+2+\cdots+N+\cdots+2+1=N^2$. See figure 4.

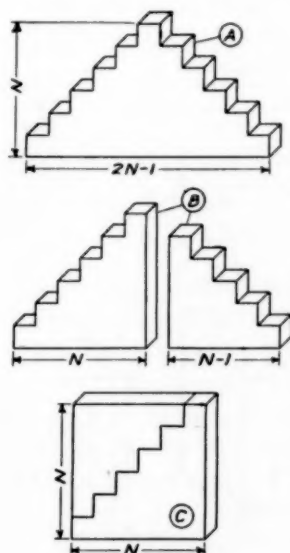


FIG. 4

- (IV) $1 \cdot 2 + 2 \cdot 3 + 3 \cdot 4 + \dots + N(N+1) = \frac{1}{3}N(N+1)(N+2)$.
See figure 5.

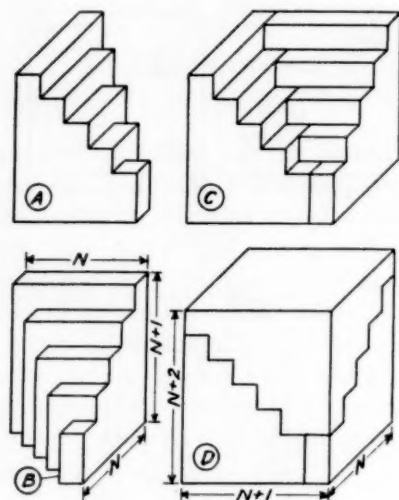


FIG. 5

- (V) $1^2 + 2^2 + 3^2 + \dots + N^2 = \frac{1}{6}N(N+1)(2N+1)$. See figure 6.

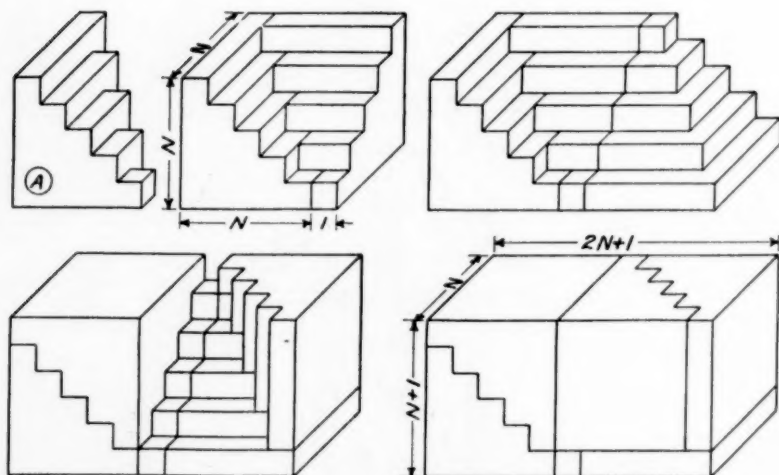


FIG. 6

(VI) $1^2 + 3^2 + 5^2 + \cdots + (2N-1)^2 = \frac{1}{3}N(2N-1)(2N+1)$. See figure 7.

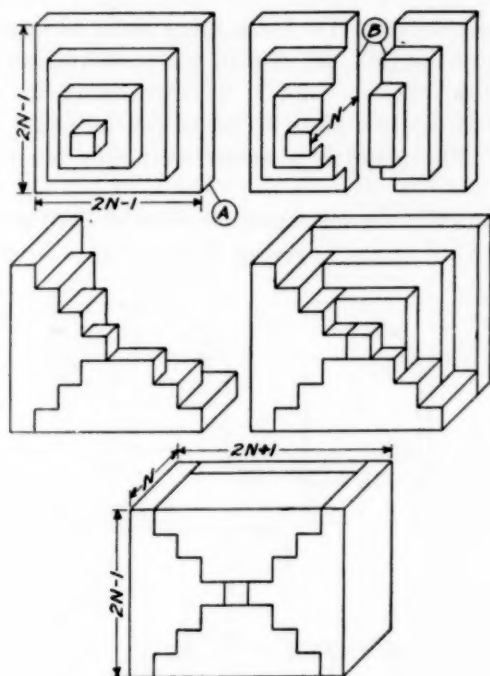


FIG. 7

- (VII) $1^3 + 2^3 + 3^3 + \cdots + N^3 = (1 + 2 + 3 + \cdots + N)^2$. See figure 9.
- (VIII) $1 = 1^3$, $3 + 5 = 2^3$, $7 + 9 + 11 = 3^3$, \cdots , the sum of the N odd integers in the N th group is equal to N^3 . See figure 10.

Each number in the left-hand member of (I) may be represented as in *A* of figure 1, giving N bars. From these the object shown in *A* of figure 2 is formed, giving a representation of the sum $1 + 2 + 3 + \cdots + N$. It is plain that two such objects can be fitted together to form a rectangle, as shown in *B* of figure 2. This rectangle, with width N and length $N+1$, represents the number $N(N+1)$. Since *A* is half of *B*, we have an illustration of (I).

Each number in the left-hand member of (II) may be represented as in *B* of figure 1, giving N bent bars. Since these can be

arranged to form a square, as shown in figure 3, we have an illustration of (II).

As in *A* of figure 1, we use bars to represent the terms in the left-hand member of (III). Assembling these to form the object shown at *A* of figure 4, we obtain a representation of the sum $1+2+\cdots+N+\cdots+2+1$. If the object be divided as shown in *B* of figure 4 the two parts can be fitted together as shown at *C*. The result is a square with side N . Thus (III) is illustrated.

Each product in the left-hand member of (IV) may be represented as in *C* of figure 1, giving N rectangles. From these can

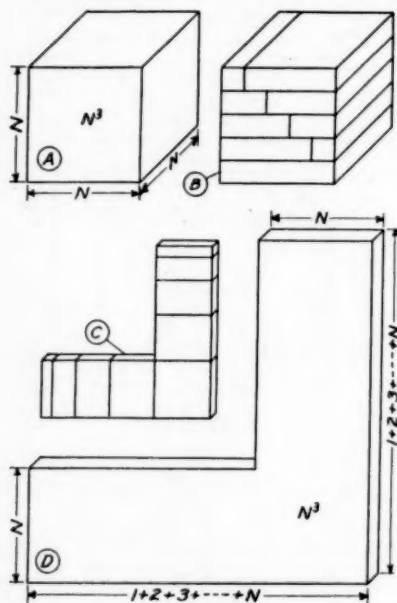


FIG. 8

be formed either of the objects shown at *A* and *B* of figure 5. It is shown in *C* and *D* of figure 5 how three such objects (one of *A*, two of *B*) can be arranged to form a rectangular solid having dimensions N , $N+1$, $N+2$. Thus (IV) is illustrated.

The left-hand member of (V) is represented by the object shown at *A* of figure 6. That a rectangular solid of dimensions N , $N+1$, $2N+1$ can be formed by using six such objects is shown in successive steps in figure 6. This illustrates (V).

The object shown at *A* of figure 7 represents the left-hand

member of (VI). This can be divided as at *B* of figure 7. The remaining diagrams of figure 7 show how three of the objects *A* (one entire, two divided) are assembled to form a rectangular solid of dimensions N , $2N-1$, $2N+1$. Thus (VI) is illustrated.

The obvious way of representing the number N^3 is by a cube with edge N , as shown at *A* of figure 8. If this be divided into layers of unit width, and the layers further divided in the manner indicated in *B* of figure 8, the parts may be arranged as in *C*. There results the solid shown at *D*. This new representation of N^3 makes possible the illustration of (VII) and (VIII).

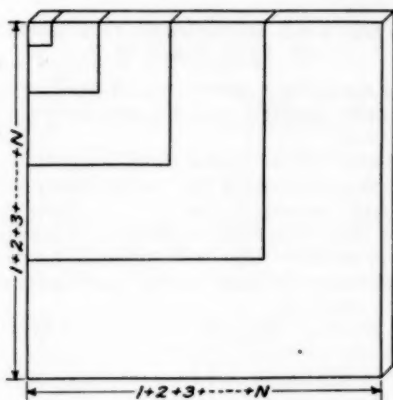


FIG. 9

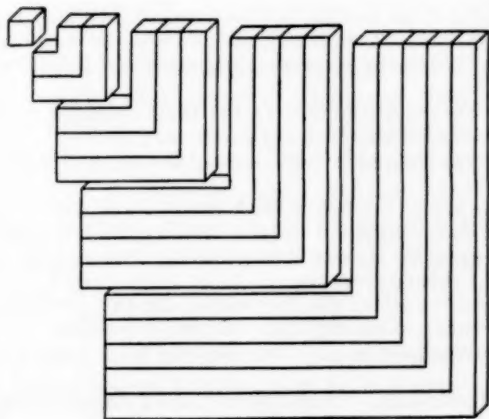


FIG. 10

If each of the numbers $1^3, 2^3, 3^3, \dots, N^3$ be represented as in *D* of figure 8 the N objects can be assembled, as shown in figure 9, to form a square with side $1+2+3+\dots+N$. Hence we have an illustration of (VII).

Again representing each of the numbers $1^3, 2^3, 3^3, \dots, N^3$ as in *D* of figure 8, it is shown in figure 10 how each object can be divided to represent (see *B* of figure 1) groups of consecutive odd integers, the number of elements in each group being the same integer whose cube is represented by that group. This illustrates (VIII).

REPORT OF THE RESOLUTIONS COMMITTEE OF THE C.A.S.M.T.

The report of the resolutions committee adopted at the St. Louis meeting was unintentionally omitted from the secretary's report in the January issue of the *Journal*.

Report of the Resolutions Committee.

It is the desire of the members of the Central Association of Science and Mathematics Teachers assembled here at this, their thirty-sixth annual convention, to give their statement of their appreciation for the untiring efforts and interests of those who have planned and carried forward to this successful termination the work of this meeting for study, inspiration, and advancement of teaching.

Therefore, be it resolved that the members of this organization give expression of gratitude:

First, to President O. D. Frank and his associates for the part they have had in planning this successful meeting.

Second, to the St. Louis Local Arrangements Committee; to Mr. W. R. Teeters and the teachers of St. Louis for their hospitality; to the Reception Committee; and to the committee which provided the many beautiful flowers.

Third, to the editor of the journal, *SCHOOL SCIENCE AND MATHEMATICS*, and his staff, the business manager and his staff, and the many contributors, for providing us with the successful magazine and helpful articles each month.

Fourth, to the Yearbook Committee for their splendid work; to Miss Elizabeth Isenbarger who designed the cover page.

Fifth, to the Hotel Coronado for the splendid room and service during the convention.

Sixth, to the speakers, musicians, and entertainers who contributed so generously to the pleasure of those attending the convention.

Seventh, to the press for making it possible for a larger number of friends to know about this convention.

Eighth, to the exhibitors at the convention for the part the instructive exhibits have taken in making this convention possible.

Ninth, to the advertisers in the *Yearbook* for their contribution to the *Yearbook*.

Tenth, to the Membership Committee for their splendid work.

JAMES P. FITZWATER, *Chairman*
HERBERT A. GRABAU
ORRA OLIVE DUNHAM

HOW SCIENCE AND MATHEMATICS ARE TAUGHT IN THE MISSOURI SCHOOLS*

BY JOHN L. BRACKEN

Superintendent of Schools, Clayton, Missouri

I value the opportunity to address this significant gathering. It is a pleasure for me to add my word of welcome to those already spoken. I would like to make this point: We in the County feel that you are meeting in the St. Louis area, including the suburbs, which form the jewels in the St. Louis necklace. We feel that we have an intimate share in this meeting. Into a Missouri session at the Department of Superintendence there came, a few years ago, a representative from Los Angeles. He asked for the privilege of the floor. He received it and invited all of us to attend a California Convention. This meeting was to be sponsored by the City of Los Angeles and by the outlying cities, as well. One lean, lanky Missourian arose and said, "I would like to ask the speaker whether I understood correctly that this convention is to be held in Los Angeles and the outlying cities. I thought that was what I heard." When told that he was correct, he said, "Well, I still don't believe that any city can out-lie Los Angeles." I want it understood that you are the guests of St. Louis and of the outlying cities.

I have wondered why a school superintendent should be included in a program such as this. A colored man in my community may have been possessed of sobriety at one time, but is seldom so possessed now. Truth telling has no part in his make-up, and theft is of minor importance. A friend heard that he had, nevertheless, just been made a deacon. He inquired about this of the colored man, saying, "You get drunk all the time, you don't tell the truth, and I have to tie all the tools down so you don't take them with you. How did you ever happen to be made a deacon?" The odd-job man replied, "I don't know, sir, unless it was because the rougher element in the church just naturally demanded recognition." You face a difficult few minutes here. What school superintendent can take a subject devoid of interest and speak interestingly or give to a vital subject any charm whatsoever? A superintendent became ill and went home about 2:00 o'clock in the afternoon. His wife

* Address delivered before the Annual Convention of the Central Association of Science and Mathematics Teachers, Nov. 27, 1936.

met him at the front door. "John," she said, "You are ill—you have a temperature." She went for the thermometer, which, as usual, was either lost or broken. She sent for the little kindergarten youngster—home for the afternoon—and told him to run over to the corner drugstore for a clinical thermometer. This was quite an order for a child of five years, but he did come close to the object of the trip. He brought back a barometer rather than a thermometer. There is a difference between these instruments. The boy's mother was interested, not in the state of the weather, but in the state of her husband's health. Not noticing the difference, however, she thrust the instrument under the tap, shook it down, and placed it under her husband's tongue. After the proper interval she withdrew it, held it up and, to her surprise, read these words, "Dry and windy."

I have a few figures I wish to present to you and a few comments I wish to make. I have referred to various authorities in regard to the things that are being done in the Missouri fields of mathematics and science—I am familiar with them in my own localities, only. We have, in the state of Missouri, 673 first class high schools. This term, "first class high schools" is technical rather than descriptive. These high schools have met the basic state requirements, and such as we are, there are 673 of us. I was rather surprised that some high schools can exist without teaching elementary algebra and remain on our first class list. Six hundred thirty-eight of these schools have courses in elementary algebra. Six hundred twenty-eight offer a course in plane geometry, and 533 follow this up with a course in advanced algebra. Solid geometry has only 103 recognitions, and trigonometry has a total of 111. In the state of Missouri there are 495 high schools which offer courses in advanced arithmetic—and you know the crimes that have been committed in the name of advanced arithmetic! Too frequently it is merely a review course. I am referring to the report for the biennium that closed in 1934: Thirty first class high schools offered courses in general mathematics. Below the high school level our work in Missouri deals with the elimination of excess arithmetical baggage and with determining the proper grade placement for the material we do use. We are trying to find where mathematics instruction should begin, beginning to try to practicalize mathematics. These tendencies are obvious in connection with mathematics teaching in Missouri. The Missouri College Union requires that two years of mathematics shall have been experienced by any student who

expects to enter any college of that Union without examination or deficiency. It means that little girls, who may not go to college after all, find it necessary to experience a second year of mathematics. Memory and tears are substituted for reasoning, but the requirements of the Missouri College Union are met, so far as the records in the principal's office are concerned. We are beginning to do more with practical mathematics—with assembling groups of children who are able to do practicalized, specialized work on advanced levels of mathematics. High school teachers, of course, say that if junior high school teachers had done a better job of teaching it would simplify the problems in the senior high schools; junior high school teachers say the same thing about elementary school teachers; the elementary school teachers say. "Look what happens down in the kindergarten"; there they say. "Look at the home conditions"; and the mothers say. "If you only knew my husband's folks!" Missouri is a melting pot of the nation. Our teachers talk as do those in your state.

A better statement in regard to trends in several forms of science is possible for the period which begins with the year 1927 and ends in 1934. I am interested in the number of general science courses which have been added to the curriculum in that time. The number has increased from 489 to 627. At the same time there is this significant increase in the high school science subject which I personally value above all others: 113 courses in biology in 1927 and in 1934 there were 348. I was rather disturbed about the separate courses in biology: four courses in botany in 1927 and only 2 seven years later; three courses in zoology in 1927 and only 2 seven years after. Those figures are not significant, however. A literary friend of mine said at the time of the beginning of the depression. "I do not know what I am going to do to turn out my material. I have had to let half my office force go." Then he added. "But, I'm keeping the other girl." There were 406 physiology courses in 1927. This number had shrunk to 106 to 1934. There are no figures available in regard to hygiene in 1927, but there were 140 in 1934. This is true, as indicated by the State Superintendent of Schools: Many people feel that in general science and biology there are offered many things pertaining to the study of hygiene which make separate offerings of this course unnecessary. Physical geography has shrunk from 27 in 1927 to 4 in 1934. The courses in physics, numbering 229 in the first of these

years, have run a consistent, increasing course as first class high schools have been increasing. I think the most significant developments in science and mathematics are occurring today below the level of the secondary schools—finding material that is worth while and interesting for children to study. Teachers, I know, are hampered by a lack of specialized material, and, at the same time, I have never found any teacher who has a zeal to teach who can be handicapped by a lack of ready made material. Perhaps we lack teachers. History-making work in the field of science in Missouri can be made in the next few years in the elementary schools.

Our State Courses of Study were written in 1927 and 1928. I wonder if you know how long ago that was. That was back in the time when Calvin Coolidge was President of the United States. You remember Mr. Coolidge, don't you? He was the man, reticent in public, voluble in private, who thought, quaintly, that there should be a complete separation between government and business! In 1927 no one knew about air conditioning except the refrigeration companies. To use a scientific term, it was B.T.U.—“Before Townsend's Utopia.” We were talking about the Russians' Five Year Plan; we had not gone alphabetical; Shirley Temple had not been born; the Baby Derby in Canada was joyously getting under way; and Mrs. Dionne was totally unconscious of the contribution she was to make to a startled world. Living has new directions. It is time for new directions in teaching. I know that the properties of the isosceles triangle remain unchanged; that similar tetrahedrons still vaguely resemble each other; and that trigonometric functions may still be termed acute. But the applications of our mathematics have been exceedingly unfortunate. Our arithmetic has been the arithmetic of armaments and ballistics. Our trigonometry has emphasized the trigger in the last two decades. Our business arithmetic has used too much red ink. We have computed per cents of poverty and unemployment. In the last two decades our mathematics has been too much the mathematics of misery.

Mathematics deals with straight thinking, thinking that can be generalized. In the lower grades we can make our Mathematics automatic in the fundamentals—satisfying the poor definition which says that we are educated so that we do not have to think. In the higher grades we can give Mathematics to the children as an instrument of thinking; we can teach straight-

line thinking. We can prove that we always get identical results from similar treatment of identical factors. Can this not work to eliminate the repetition of foolish mistakes in life's procedures? Cannot we submit more of life's problems to inexorable scrutiny in the cold light of mathematical reasoning? Mathematics is not a thing separate. The teacher can, if she is suffused with life and conscious of living, function with her subject in the life processes of her students.

Similar statements may be made in regard to science. Photosynthesis and specific gravity are unchanged. Fermentation is still eminently in fashion. But scientific knowledge is expanding. Teaching procedures develop. It is necessary that we keep pace with time. A scientific attitude is necessary. Some of our boys and girls must grow up so that they will love science and pursue her. It is important, certainly, to appreciate science; to understand the contributions which science has made; and to have some remote idea of the possibilities which science may offer. It is more important that we shall have and shall give to our children a proper scientific perspective. Teachers are zealous. They are concerned with subjects of their own specialization. For people in general we must temper scientific instruction. Regardless of what we have taught, the man on the street has believed too much in science. Science has been assigned attributes which it does not possess. The man on the street has said and has believed that science has challenged religion, that science will replace religion. That cannot be true, for science has no Messiah, no explanations of beginnings and no hazards beyond the veil of time. It cares too little sometimes for purposes and directions as they evolve. Science has not added properly to many of the enduring satisfactions of life. This is not, in my definition, the age of science. It is the age in which scientific methods are developing and the age in which science has not been properly assimilated into the life processes of our people. In the last quarter of our century there has been amazing scientific development. In this quarter of a century we have seen the bloodiest, the most destructive war of all history. Science helps now to prepare another, more devastating war, a war which appears inevitable. It allowed—perhaps assisted, the greatest depression we have ever known to engulf the world. It has not brought us out of the wallow we have been in. We have seen more warfare and human wreckage in these twenty-five years than in any similar period in all history. Science, if it is

to justify its claims, must help man realize himself, and not to destroy himself. I am trying to say to you that science must contribute increasingly to the values of living, but that science, itself, is not these values.

A friend of mine journeyed around the world. In India he wanted to have, above all, one particular experience. He wanted a conversation with a Mahatma—a wise man. They led him down a mean street, through an alley, to a tiny house, and into a room of this house where he saw the Mahatma seated upon what was perhaps a priceless sacred rug. The only other piece of furniture was a battered electric fan which struggled vainly to bestir the air in the room. The Mahatma was quaintly dressed. His hair was parted in the middle and touched the floor on either side as he sat on the floor. My friend sat down to scoff,—and remained to learn. This was one of the wisest men he had ever met. He spoke of the Five Year Plan in Russia, and discussed it intelligently. He appraised radioactivity as an arrestive agent for cancer. He was the only man my friend had seen who seemed to have a real glimmering of what the Einstein Theory is about. My friend, leaving, said, "Father, I wonder if you have any message you would care for me to carry back home with me." He said, "Yes, my son," and then, "My message is this: Your American people should learn to be more practical." My friend said, "But, Father, I'm afraid you don't understand after all. We are the most practical people of the world. Look at the discoveries that come from our test tubes, look at the products of our mechanical genius." The Mahatma said, "Yes, my son, there seems nothing you cannot create—in the physical world. You can travel rapidly from one place to another. But the American people have not yet reached the point of practicality. They have never discovered the values of living they most desire, and then resolved to go ahead and achieve those values no matter how science and engineering may stand in the way." Life is not a formula. Its genuine values do not come from test tubes. But the extension of formulae, their learning and their application; the findings of the test tube and the application of the thinking which they epitomize may add more richly to these values than we have thus far allowed them to do.

I do not envy many of you people the grubby things you must do daily in your classrooms while I do similar tasks in my office. I do not envy you the details of your repetitious tasks. I do

not envy you in the little; I do envy you in the large. I envy you your opportunity so to teach that sometime it may be said of you as it was said of the Great Teacher—"Whether this man be a sinner, I know not. This thing I know: He opened my eyes."

TEACHER, WHAT'S YOUR ANSWER?

BY CHARLES H. STONE, *Boston*

Do you have your pupils stand or sit to recite? Why?

What attention do you pay to seating favorably pupils who have defective vision? Or hearing?

Do you attempt to introduce at proper times environmental chemistry (the chemistry of neighboring industries) into your recitation room? Why?

Do you conduct excursions now and then to such industrial plants as have anything of chemical interest, such as; the creamery, the blacksmith shop, the foundry, the plating shop?

What attempt do you make to adjust your instruction so as to fit a few students for college and at the same time give the rest of the class the kind of chemistry you feel they should have? (That's a tough one, what?)

Is there a bulletin board in your room? Do you use it for putting up lesson assignments, clippings from newspapers and magazines, pictures, samples of students' work, etc? Do you appoint some student each week to act as editor of this board? Why?

Is there in the corridor of your school an exhibition cabinet in which may be displayed samples of your students' work? Why and how much do you use it?

To what extent do you try to bring the chemistry of the home into your classroom; baking powders, cleaning agents, silver cleaning, etc?

Have you organized a Science Club in your school? What was the idea?

What do you consider to be the chief end to be attained in the study of chemistry?

In giving tests, do you use the newer forms (choice of answer, missing word, + or - before sentence, etc., or do you use the older type of test? What reasons can you give for your choice?

In giving written tests, how do you prevent cribbing? (It can be done, even in a crowded classroom.)

In the recitation, do you believe that the best teaching is done by standing before the class and telling all about everything in the lesson?

Have you ever considered the encouragement of correspondence with teachers in distant schools with a view to interchange of views and material?

Do you know where much material of value in teaching may be obtained by simply asking for it?

What do you consider to be the chief end to be attained by laboratory work?

To what extent do you permit conversation in the laboratory? Why?

When conducting a laboratory class, do you have the students come to you as occasion arises or do you circulate about the room? Why?

Do you believe that an experiment should be carried through to its logical end? For example, in the preparation of hydrogen, would you have the pupil also obtain the zinc sulphate in its two pure forms? Why?

CHILDREN'S EXPERIENCES IN ELEMENTARY SCIENCE RELATED TO PROBLEMS OF CURRENT LIVING—FIRE AND AIR*

BY DAVID W. RUSSELL

National College of Education, Evanston, Illinois

When science was making its way into the elementary school curricula it came about mostly through intense interest on the part of the children. As the importance of elementary science grew curriculum specialists and teachers began to search seriously for some organized fashion to shape the science courses of study and to justify and guide the children's activities. So the experts got busy and established many principles of elementary science curricula construction. Some believe that the subject matter should be based on child interests alone, others subscribe to the preparation theory and a very popular plan is to provide activities to promote scientific thinking at an early age. Among other plans are those stressing environment, correlation and integration, children's experiences, children's needs, current problems of good living, and mental ability to master science principles at an early age. Many philosophies have been advanced for curriculum construction and for determining subject matter content but no one knows just which one of these various plans or which combination of them really meets and fits into our rapidly changing social scheme.

Along with the problem of curricula content the teacher is confronted with the teaching techniques. Lists of techniques have been arranged but they can really be boiled down to three with the personality and ingenuity of the teacher being the important and the variable factor. In many schools, mostly the progressive schools, the incidental plan is used with considerable success. In many schools the unit plan is followed with stress on individual differences, homogeneous grouping, or subject content as the justification of technique. And then we still have great emphasis on the correlation and integration plan with the teacher searching for facts that can be converted into activities that in turn can be related to classroom experiences in other fields of study. Occasionally a school will be found using classroom experiences in science as the center of interest with the

* This paper, illustrated with lantern slides was read before the Elementary Science Section, Central Association of Science and Mathematics Teachers. St. Louis, November 27, 1936.

other subjects related to them. This is unusual but offers an excellent avenue for experimentation and approach to subject matter in a new way, and new ways do motivate children!

But the purpose of this discussion is not to debate the wisdom of science curricula techniques or to justify the validity of certain teaching techniques. My talk is to illustrate two experiences in science instruction that relate to instruction in problems of current living. Regardless of your philosophy of science education or suitable techniques, it is hoped that the following illustrated description will offer some new ideas in presenting some practical knowledge that is useful in the living and health habits of children in the upper elementary grades.

To start the first unit we begin with an observation. A sixth grade boy is fussing with a fire extinguisher on his way to class. There are several of them in the building that have been there for years but have little meaning. A little conversation was overheard concerning these instruments. But they are "taboo" and must not be handled. It is suggested by the teacher that it might be interesting to investigate these fire extinguishers and needless to say curiosity and interest are aroused. The local fire warden makes his annual inspection sometime during the fall and this might be a good time to prescribe a little instruction in fire prevention. It isn't in the course of study but fortunately such an experience might be arranged.

The science period arrives and the science instructor sees the wisdom of carrying through with this interest and an opportunity to give instruction in an item of everyday living. So the class members collect the extinguishers after permission is secured and the work begins. The first logical step is to use the apparatus and there are not many sixth graders who object to "playing with fire." So the class gathers wood for a fire and they divide themselves into groups to represent fire companies. The fire is built on the playground, it is ignited, the fire companies come to the rescue and within a minute or so the streams from the extinguishers are pouring on the flaming mass. In preparation the children have been instructed in extinguishing a fire, where to aim the stream, and a few incidentals about the apparatus. Before long the fire is out but the lesson is not over, no, it has just begun! These metal cans have to be cleaned, recharged, and replaced for school protection. This is an easy task. The proper amount of sulphuric acid, bicarbonate of soda and tap water is all that is needed but it is important that this work

be done under the careful supervision of the science teacher. The extinguishers are then replaced in their proper stations in the building and the first part of the unit is over. There is a matter of expense that will not only interest school administrators but provide a little practical arithmetic for the mathematics classes. How much material will the class need, how can it be purchased, and where? The average up-side-down fire extinguisher can be recharged for about thirty-five cents or less. The simple chemistry that is involved is another interesting phase of this activity.

Continuing with this experience of activity, manipulation, explanation, and calculations plans are devised to give each child information concerning his activities in an emergency. Fire warnings are discussed, first aid considered, and an investigation of the nearest fire plugs and fire alarms is planned. In one instance the class supervised and arranged a school fire drill. It was a well planned affair with considerable interest on the part of the science class. A unit, or series of classroom experiences as some educators prefer to call it, of this kind may well conclude with an assembly program or a visit to the local fire station. We were very fortunate when our class visited the local fire department. The alarm was sounded while we were inside and the children saw the whole procedure. But soon the fire engines returned. It was a false alarm. Soon after the class was given an inspection tour of the living quarters of the firemen. They were allowed to slide down the pole and see the alarm apparatus.

An ingenious teacher can add and subtract many experiences to a science activity of this kind. It can be correlated, it can be used as a separate unit, and it can be motivated by utilizing children's interests. In any event a study of fire can be made a vital issue in the lives of these children and a real problem of current living can be handled. The fire unit, as it has often been called, has always been one of the most popular activities of the sixth grade science class and after these children have been promoted to the upper grades they will often remark to their teacher, "Do you remember when we used those fire extinguishers?" The slides that have just been shown will illustrate a unit of this kind in actual operation.

But all schools do not have fire extinguishers of this type and all schools do not have a situation that will lend itself to this type of science teaching so we are including another series of

classroom experiences that does concern all schools and homes as well, especially since winter is coming on. This is the question of air, or we might call it air conditioning.

Though it had occurred to me many times it wasn't until a certain situation arose that the idea of the study of air presented itself as a study of vital interest to elementary school people. One brisk January day there was considerable yawning in a classroom and some of the children seemed to have the "fidgets." One of the children suggested that the room was too hot and it was. The thermometer was up to 79° and the heat was coming into the room at full blast. A discussion was started and it was explained that there is something more than the temperature of air that contributes to proper air conditioning. The next day most of the children brought in thermometer readings of their living rooms at home. They ranged from 70° to 85° ! The apartments were the hottest. The matter of humidity became a topic for discussion and it was decided to measure the temperature and humidity of the classrooms and make a recommendation to the building and grounds committee. An investigation of methods of measuring humidity was made and it was discovered that a simple hygrometer could be made with inexpensive thermometers, some wicks, and bottles. The work began. In the picture you will see the class making their hygrometers in the shop. It didn't take long, in fact, just three shop periods. Yes, two thermometers were broken but on the whole we did quite well.

With the instruments made the class made charts to record the readings. In one or two cases decimals became an issue when centigrade thermometers were used. A home made hygrometer was put in each of several classrooms. Each day the committees in charge of the various rooms would make their reading at the same hour and record the findings on the chart. Sooner or later the barometer would become topic for conversation for our psychometric tables gave the relative humidity according to air pressure. Along with this weather maps were introduced and weather prediction became another activity. All of you can see the unlimited possibilities and the correlated activities that could be developed from this study. The danger to be avoided was that the children were not led beyond their scope of understanding and beyond the purpose of the investigation. But it was still a problem of current interest, or let us say, a study that contributed definitely to the needs of children in their everyday

living. The subject of colds and influenza was an added topic for conversation and study and the school doctor was available for some medical advice.

But continuing with relative humidity it was found that several of the classrooms were poorly air-conditioned and over-heated and it seemed that the class was touching on one of the great American complexes known as the "heat complex."

The unit continued and a final report was made with the hope that corrections in room temperatures would be made as far as possible. In one instance the subject of water was continued and various experiments with water and ice continued. When does water freeze? Does an electric fan cool the air? Do leaves actually expel water into the air? Simple transpiration experiments were tried and laboratory experiments were conducted by the children as illustrated by the pictures. To the science teacher this brings the question, should the elementary science teacher always demonstrate or should the children perform their own experiments when the facilities are available? Common sense answers the question in most cases for if the experiments are simple enough for the children to perform accurately it seems logical that they should perform them. On the other hand if their performance is doubtful it is far better guidance and teaching to have a good demonstration by the science instructor. In these pictures the experiments were simple enough for the children to handle.

The study of air and water can be concluded in many ways. Actually it brings responses from the parents, sometimes favorable and sometimes unfavorable if the outcome becomes a criticism of heat control in the child's home. Assembly programs are possible or just recommendations to the principal concerning room temperatures and humidity. An excellent field trip to correlate with the study is a visit to the heating plant or the air conditioning plant of theatres and air conditioned Pullman cars. The school heating plant can be explored and a general survey made of the kind of fuel that is used, the work of the thermostat, thermometer, and other related topics.

These two series of teaching experiences which have been explained in this one-half hour talk have been the result of three years of experimentation with these units. The plans of study have been altered each time and in no two applications were the outcomes exactly the same. But it is evident that the various experiences have brought forcibly to the child's attention the

problems of fire control, fire protection, and the importance of air to good living conditions in the home and in school. These may be called teaching experiences dealing with problems of current living, science instruction that should contribute some vital information to the child that will have practical wholesome value. If you will try some instruction of this kind with variations to meet the situations in your school you will find the results amazing.

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All science consists in pushing difficulties further back.—Schuster.

VISUALIZING THE CENTER OF GRAVITY

BY JOHN B. LEAKE

Crane Technical High School, Chicago, Illinois

Secondary school Physics courses usually include methods for determining the center of gravity. Experimental proof is secured with meter sticks and weights. As this problem finds frequent application in airplane design, in which most boys are interested, we have developed two pieces of apparatus, with which the center of gravity is found experimentally; using a small airplane, or its separated parts.

Fig. 1 shows the device for duplicating the commercial practice of finding the center of gravity of a completed plane, by weighing both ends, and solving the lever equation. This ap-

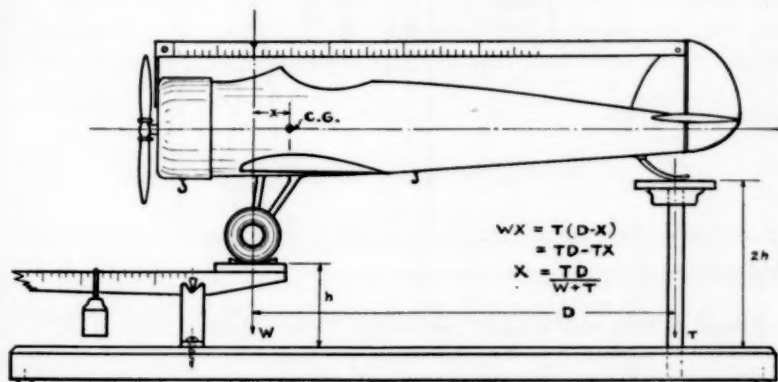


FIG. 1. Finding center of gravity of completed plane.

paratus consists of a base on which is mounted a balance, and a removable support. An airplane weighing about three pounds gives good results. A metal monoplane, nicely enameled, can be bought for about \$2.00. One or two extra weights are provided, to be hung on hooks shown on the drawing. These represent shift of load, and change the center of gravity.

The experiment consists of finding the wheel reaction, by placing the plane as shown in the drawing; then finding the tail reaction by removing the vertical support, reversing the plane, and balancing the plane on a knife edge, held under the upper horizontal scale provided for the purpose. The check on our fairly rough apparatus is within one millimeter.

Fig. 2 shows the device for finding the center of gravity of a plane from the weight and spacing of its parts, and illustrates the mathematical method of solving this problem from data on the design drawing.

The experiment consists of drawing a sketch of a proposed plane, hanging the parts of the model on the balance hooks, and finding the point of concentrated weight by shifting the sand bucket. Using the lever distances to the parts, as measured from the balance pivot, the center of gravity is then calculated by moment equations. As the two results check very closely, the

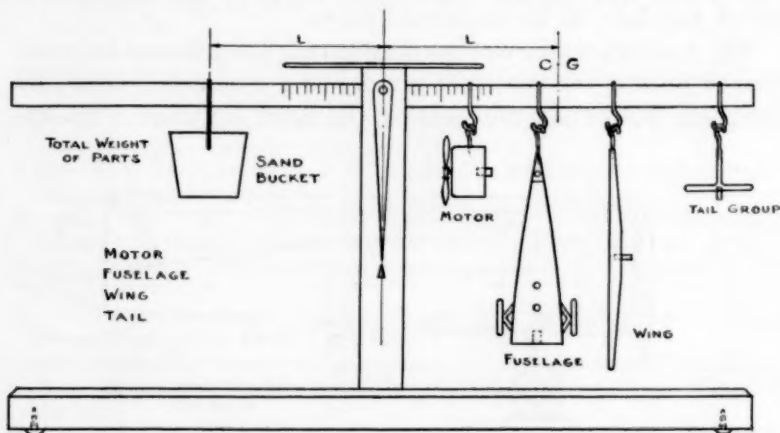


FIG. 2. Center of gravity determination from turning moment of parts.

boy gets a visual demonstration of the meaning of the mathematical process. In detail, the operations for this experiment are as follows:

1. Sketch the side view of a plane, of length less than a balance arm. Mark in the distance between C. G. of the parts.
 2. Weigh parts and record on the sketch.
 3. Assemble the plane, and hang from the balance arm.
 4. Place sand bucket at equal distance on opposite arm, and adjust sand till beam tips.
 5. Disassemble plane, and hang parts on hooks, at spacing shown on sketch.
 6. Transfer distance from pivot to first hook onto the sketch.
 7. Move sand bucket until beam tips. C. G. of the group of parts must be located as far from the pivot, as is the bucket, because the weight on each side of the pivot is equal, and the lever is in balance.
- Note. This can be proved by hanging all the parts from a hook, spaced the same as the bucket from the pivot.
8. Mark the C. G. position on the sketch, and figure its distance from the motor C.G.

9. Fill in the values in the table below,

Part	Lever arm \times Weight of part. = Turning Moment.		
Motor	_____	_____	_____
Fuselage	_____	_____	_____
Wing	_____	_____	_____
Tail	_____	_____	_____
Total	_____	_____	_____

L.A.

10. Divide the total turning moment, by the total weight. This gives the lever arm to the C.G. of the whole job.

Note, this operation is similar to sliding the bucket along the beam until the product of its weight times its distance to the pivot, equals the total effect of the parts acting at their respective distances.

11. Locate the C.G. calculated on the sketch. It should check closely with that obtained experimentally.

12. Repeat the calculation for a plane with different spacing of parts.

13. Using the same spacing of parts use a different pivot distance. What effect has the pivot distance taken, upon the location of the C.G.?

The above equipment can be easily constructed in the school shops at low cost, and will interest many boys who are not attracted by experiments seemingly removed from their life interests.

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON

State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution as on the following pages.

The editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutions are correct, the ones submitted in the best form will be used.

LATE SOLUTIONS

1460. 2, J. E. Campbell, Regina, Canada.

1466. Proposed by James A. Lemon, Randolph High School, Englewood, Ohio.

Prove that in any triangle (not isosceles) the difference of any two sides is to the difference of the projections of these two sides on the third as the third side is to the sum of the two sides.

Solution by the proposer.

Let ABC be the given triangle with AD an altitude.

$$\overline{AC}^2 = \overline{CD}^2 + \overline{AD}^2 \text{ and } \overline{AB}^2 = \overline{BD}^2 + \overline{AD}^2$$

$$\text{Hence } \overline{AC}^2 = \overline{CD}^2 + \overline{AB}^2 - \overline{BD}^2 \text{ or}$$

$$\overline{AC}^2 - \overline{AB}^2 = \overline{CD}^2 - \overline{BD}^2 \text{ or}$$

$$\frac{AC - AB}{CD - BD} = \frac{CD + BD}{AC + AB} = \frac{BC}{AC + AB}.$$

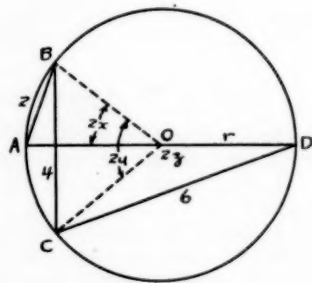
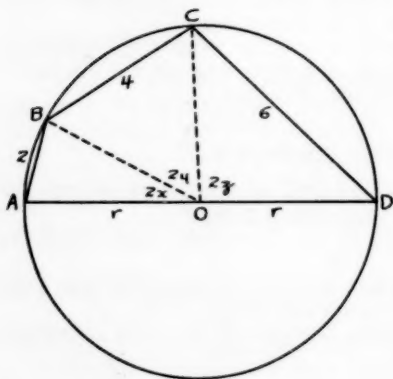
Note: See EX. 11, page 194, Smith, Reeve, and Morss, "Text and Tests in Plane Geometry."

Solutions were also offered by Max Fowler, Centralia, Ill., John Kinsella, Newburgh, N. Y., W. E. Buker, Pittsburgh, Pa., Earle M. Bigsbee, Ballston Spa, N. Y., Adrian Struyk, Paterson, N. J., Hugo Brandt, Chicago, William W. Taylor, Port Arthur, Texas, Julius Freilich, Brooklyn, N. Y., A. R. Haynes, Bert Fowler, Isadore Chertoff, Bayonne, N. J., Hyman Marcus, New York City, J. E. Tuer, Orillia, Ontario, Canada, John M. West, Talequah, Okla., Aaron Buchman, Buffalo, N. Y., David Rappaport, Chicago, Charles W. Trigg, Los Angeles, and J. Slavin, Brooklyn.

1467. Proposed by Hugo Brandt, Chicago.

A quadrilateral $ABCD$ is inscribed in a circle with $AB=2$, $BC=4$, $CD=6$, and diameter DA . Find DA .

Solution by Charles W Trigg, Cumnock College, Los Angeles.



Case I. Convex quadrilateral.

Let $AO=OD=OB=OC=r$, $\angle AOB=2x$, $\angle BOC=2y$ and $\angle COD=2z$.

Then $r \sin x = 1$, $r \sin y = 2$ and $r \sin z = 3$. Now $x + y + z = \pi/2$ so $\sin z = \cos(x + y) = \cos x \cos y - \sin x \sin y$. Substituting,

$$r \left(\sqrt{1 - \frac{1}{r^2}} \sqrt{1 - \frac{4}{r^2}} - \frac{2}{r^2} \right) = 3.$$

$$\sqrt{r^2 - 1} \sqrt{r^2 - 4} = 3r + 2.$$

$$r^4 - 14r^2 - 12r = 0,$$

which evidently has not more than one positive root, $r = 4.11309$, as determined by Horner's method. Hence $AD = 2r = 8.22618$.

It follows that $\sin x = 0.24313$, $\sin y = 0.48625$, $\sin z = 0.72938$ whence $x = 14^\circ 4'$, $y = 29^\circ 6'$, $z = 46^\circ 50'$.

Case II. Crossed quadrilateral.

Here the same relations exist as in Case I except that $y + z - x = \pi/2$, so $\sin z = \cos(y - x) = \cos x \cos y + \sin x \sin y$. Thus the equation $r^4 - 14r^2 + 12r = 0$ is secured, which has an obviously extraneous positive root, 0.902 and another positive root, $r = 3.20191$ so $AD = 6.40382$.

It follows that $\sin x = 0.31231$, $\sin y = 0.62463$, $\sin z = 0.93694$, whence $x = 18^\circ 12'$, $y = 38^\circ 39'$, $z = 69^\circ 33'$.

Solutions were also offered by J. E. Tuer, Orillia, Ontario, Canada, E. M. Bigsbee, Ballston Spa, N. Y., John Lake, Fillmore, N. Y., Hyman Marcus, New York City, A. R. Haynes, Tacoma, Washington, Julius Freilich, Brooklyn, N. Y., A. MacNeish, Chicago, Adrian Struyk, Paterson, N. J., John Kinsella, Newburgh, N. Y., John R. Whyte, Toronto, Canada, W. E. Buker, Pittsburgh, Pa., Gordon Ludwig, San Pedro, California, and Bob Minamiji, Compton Jr. College.

1468. Proposed by Amory R. Haynes, Tacoma, Washington.

Simplify

$$\frac{x^3 - 3x + (x^2 - 1)\sqrt{x^2 - 4} - 2}{x^3 - 3x + (x^2 - 1)\sqrt{x^2 - 4} + 2}$$

First Solution

By Hyman Marcus, New York City.

Solution: The given expression is equal to

$$1 - \frac{4}{x^3 - 3x + (x^2 - 1)\sqrt{x^2 - 4} + 2}$$

$$= 1 - \frac{4}{(x-1)^2(x+2) + (x^2-1)\sqrt{x^2-4}} \quad (\text{Since } x^3 - 3x + 2 = (x-1)^2(x+2))$$

$$= 1 - \frac{4}{(x-1)} \frac{1}{(x-1)(x+2) + (x+1)\sqrt{x^2-4}}. \quad (1)$$

Rationalizing the denominator, (1) equals

$$1 - \frac{4}{(x-1)} \left(\frac{(x-1)(x+2) - (x+1)\sqrt{x^2-4}}{(x-1)^2(x+2)^2 - (x+1)^2(x+2)(x-2)} \right)$$

$$\begin{aligned}
 &= 1 - \frac{4}{(x-1)(x+2)} \left[\frac{(x-1)(x+2) - (x+1)\sqrt{x^2-4}}{(x-1)^2(x+2) - (x+1)^2(x-2)} \right] \\
 &= 1 - \frac{(x-1)(x+2) - (x+1)\sqrt{x^2-4}}{(x-1)(x+2)} \\
 &= \frac{(x+1)\sqrt{x^2-4}}{(x-1)(x+2)}.
 \end{aligned}$$

Second Solution

By Charles W. Trigg.

Let $x-1=a$, $x+1=b$, $x-2=c$, and $x+2=d$.

Then upon substitution the given expression becomes

$$\frac{b^2c + ab\sqrt{cd}}{a^2d + ab\sqrt{cd}} = \frac{b}{a} \cdot \frac{abcd + (a^2d - b^2c)\sqrt{cd} - abcd}{a^2d^2 - b^2cd} = \frac{b\sqrt{cd}}{ad} = \frac{(x+1)\sqrt{x^2-4}}{(x-1)(x+2)},$$

which might also be written in the form

$$\frac{(x+1)\sqrt{x-2}}{(x-1)\sqrt{x+2}}.$$

This problem appears on page 107 of "Mathematical Nuts" (1936 Revised) by S. I. Jones, together with a solution which does *not* involve substitution.

Solutions were also offered by A. MacNeish, Chicago, Andrew McWyrghinchbeath, State College, Pa., Kate Eckles, Columbus, Mississippi, A. R. Haynes, Tacoma, Wash., Isadore Chertoff, Bayonne, N. J., Hugo Brandt, Chicago, and M. Freed, Los Angeles, Calif.

1469. Proposed by H. E. Tester, Isleworth, England.

Find the condition that the line $y=mx+c$ be tangent to the curve $x^3+y^3=3xy$.

Solution by Hyman Marcus, New York City.

Substituting $y=mx+c$ in $x^3+y^3=3xy$ we have

$$f(x) = x^3(1+m^3) + 3mx^2(mc-1) + 3cx(mc-1) + c^3 = 0. \quad (1)$$

The condition that $y=mx+c$ be tangent to $x^3+y^3=3xy$ is equivalent to the condition that (1) has two equal roots, i.e., that $f'(x)=0$ and $f(x)=0$ shall have the same root x . Hence we have, differentiating (1) and dividing by 3,

$$x^2(1+m^3) + 2mx(mc-1) + c(mc-1) = 0. \quad (2)$$

Multiplying (2) by x and subtracting from (1) we have

$$mx^3(mc-1) + 2cx(mc-1) + c^3 = 0. \quad (3)$$

Multiplying (2) by c and (3) by m and subtracting, we get

$$x^2 = \frac{mc - c^2(mc-1)}{c(1+m^3) - m^2(mc-1)} = \frac{c^2}{c+m^2}$$

$$\therefore x = \frac{c}{\sqrt{c+m^2}}.$$

Substituting this value in (2) we have

$$\frac{c^2(1+m^2)}{c+m^2} + \frac{2mc(mc-1)}{\sqrt{c+m^2}} + c(mc-1) = 0.$$

$$\therefore \frac{2(mc-1)}{\sqrt{c+m^2}} = -\frac{(c^2+2cm^2-m)}{(c+m^2)}.$$

Squaring both numbers and collecting terms, we have

$$c^4 + 6mc^2 + 4(m^2-1)c - 3m^2 = -0.$$

A similar solution was offered by the proposer. Hugo Brandt and Aaron Buchman used the parametric form of the given equation by substituting $y=tx$, in terms of t each found the required values of m and c :

$$m = \frac{2t-t^4}{1-2t^2} \text{ and } c = \frac{3t^2}{2t^2-1}.$$

Other solutions were also offered by Clyde A. Bridges, Mackay, Idaho, J. E. Tuer, Orillia, Canada, and Andrew McWyrghlinchbeath.

1470. Proposed by Aaron Buchman, Buffalo, N. Y.

In a right triangle, with hypotenuse, c , and legs a and b , if $(a+b)^4 - (a-b)^4 = 2c^4$, find the acute angles.

Solution by Julius Freilich, Brooklyn, N. Y.

$$(a+b)^4 - (a-b)^4 = 2c^4.$$

Expanding, we obtain $8a^3b + 8ab^3 = 2c^4$

$$8ab(a^2+b^2) = 2c^4 \text{ or } 8abc^2 = 2c^4 \text{ and } 4ab = c^2$$

$$\therefore \frac{a}{c} \cdot \frac{b}{c} = \frac{1}{4}, \text{ from which } \sin A \cos A = \sin 2A = \frac{1}{2}$$

$$\therefore \sin SA = \frac{1}{2} \text{ and } 2A = 30^\circ, \text{ from which } A = 15^\circ, B = 75^\circ.$$

Solutions were also offered by Andrew McWyrghlinchbeath, Max Fowler, David Blackwell, University of Illinois; Howard R. Harold, Tonkawa, Okla., Charles W. Trigg, Los Angeles, Hugo Brandt, Chicago, John Kinsella, Newburgh, N. Y., David Rappaport, Chicago, E. M. Bigsbee, Ballston Spa, N. Y., Adrian Struyk, Paterson, N. J., A. MacNeish, Chicago, Hyman Marcus, New York City, A. R. Haynes, Tacoma, Wash., Isadore Chertoff, Bayonne, N. J., J. E. Tuer, Orillia, Ontario, Canada, William W. Taylor, Port Arthur, Texas, and the proposer.

1471. Proposed by H. R. Mutch, Glen Rock, Pa.

Find the values of a , b , and c , so that $4x^6 - 24x^5 + ax^4 + bx^3 + cx^2 - 40x + 25$ is a perfect square.

Solution by Hugo Brandt, Chicago.

What values for a , b , c will make $4x^6 - 24x^5 + ax^4 + bx^3 + cx^2 - 40x + 25$ a perfect square?

The square sought is evidently of the form $(lx^3 + mx^2 + nx + p)^2$, developing this, it becomes

$$l^2x^6 + 2lmx^5 + (2ln+m^2)x^4 + 2(lp+mn)x^3 + (2mp+n^2)x^2 + 2npx + p^2.$$

By comparing the coefficients, we find:

$$4 = l^2; -12 = lm; -20 = np; 25 = p^2.$$

$$l = \pm 2, m = \mp 6; p = \pm 5; n = \mp 4.$$

$$\text{and } a = 2ln + m^2 = \mp 16 + 36 = 20; 52$$

$$b = 2(lp + mn) = 2(\pm 10 \pm 24) = 68; -68$$

$$c = 2mp + n^2 = \mp 60 + 16 = -44; 76.$$

The set $a = 20, b = 68, c = -44$ will make

$$4x^6 - 24x^5 + 20x^4 + 68x^3 - 44x^2 - 40x + 25 = (2x^3 - 6x^2 - 4x + 5)^2 \text{ or} \\ (-2x + 6x^2 + 4x - 5)^2.$$

The set $a = 52, b = -68, c = 76$ will make

$$4x^6 - 24x^5 + 52x^4 - 68x^3 + 76x^2 - 40x + 25 = (2x^3 - 6x^2 + 4x - 5)^2 \text{ or} \\ (-2x^3 + 6x^2 - 4x + 5)^2.$$

Solutions were also offered by E. M. Bigsbee, Ballston Spa, N. Y., Kate Eckles, Columbus, Miss., Charles W. Trigg, Los Angeles, Margaret Joseph, Milwaukee, Wis., Herman O. Makey, Fort Wayne, Ind., A. MacNeish, Chicago, A. R. Haynes, Isadore Chertoff, Bayonne, N. J., Hyman Marcus, New York City, J. E. Tuer, Orillia, Ontario, Canada, A. G. Watson, Toronto, Ontario, W. E. Buker, Pittsburgh, Pa., Andrew McWyrnglinchbeath, Max Fowler, University of Illinois, David Blackwell, University of Illinois, and Howard R. Harold, Tonkawa, Okla.

HIGH SCHOOL HONOR ROLL

The editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

For this issue the Honor Roll appears below:

1466. Jack Newbrough, Phineas Banning H. S., Wilmington, Calif.

1470. A. G. Watson and Colin S. Lazier, Upper Canada College, Toronto.

PROBLEMS FOR SOLUTION

1484. *Proposed by Hugo Brandt, Chicago.*

Given a point, P , to construct an equilateral triangle, ABC , so that $PA = 3$, $PB = 4$, and $PC = 5$. Also calculate the length of side, AB .

1485. *Proposed by H. R. Mutch, Glen Rock, Pa.*

Problem: Quadrilateral $ABCD$ is inscribed in a circle and $AC \perp BD$. AD and BC meet at E , AB and CD meet at F ; tangents at B and D meet at H . Prove by elementary geometry that AC and EF pass through H .

1486. *Proposed by Isadore Chertoff, Bayonne, N. J.*

Prove $\log_a a \cdot \log_a b \cdot \log_a c \cdot \log_a d \cdot \dots \cdot \log_a m \cdot \log_a n = 1$.

1487. *Proposed by David Rappaport, Chicago.*

A circle is inscribed in a square whose side is a . Find the radius of the small circle inscribed in the corner of the square tangent to the two sides of the square and the given circle.

1488. *Proposed by G. W. Ames, Milan, Missouri.*

Two perpendicular lines meet at A . A fixed circle with center, O , is tan-

gent to one of the perpendiculars at A . If a secant of this circle meets OA at K , the circle at P and the other line at R , and if arc $AP = AR$, find the limiting position of K as P approaches A .

1489. *Proposed by L. S. Gray, Tacoma, Wash.*

An inverted right circular cone has an altitude of 16. The generating angle is 30° . Find the radius of the sphere, which, when carefully dropped into the cone full of water, will cause the greatest overflow.

SCIENCE QUESTIONS

February, 1937

Conducted by Franklin T. Jones

(Send all communications to Franklin T. Jones, 10109 Wilbur Avenue, S. E. Cleveland, Ohio.)

This department is a forum for discussing Tests, Experiments, Pedagogical Questions, Scientific Happenings. Practical Applications of Scientific Principles, Popular Beliefs and Misapprehensions concerning Scientific Matters, Newspaper Science, Think Problems (mostly scientific). Trick Questions, Borderline Science Questions involving Mathematical Treatment, College Entrance Examination Questions and Problems, Any Problem or Question that will help teachers to make Science Teaching interesting.

The discussion usually takes the Question and Answer Form. Readers, whether teachers and students or outside schools walls, are invited to propose Questions or Problems and to answer Problems and Questions proposed by others.

As a Mode of Recognizing contributors, the Guild of Question Raisers and (GQRA) has been formed and more than 150 contributors have already been admitted to Membership. Classes or individuals, may become members by proposing a question or submitting an answer.

JOIN THE GQRA

GUILD QUESTION RAISERS AND ANSWERERS (GQRA)

Propose a question or solve a problem and become a member.

NEW MEMBERS—February, 1937

157. Clyde A. Bridger, P.O. Box 89, Mackay, Idaho.
Question on Reciprocating Engine (Trade No. 3)
158. Collis M. Bardin, Washington Union High School, Route 6, Box 100,
Fresno, California
Tests "Whether Our Science Courses are Affecting Students in
Practical Ways" (Member of Mathematics Club)
159. Frederick Wolter, Student, Peru State Teachers College, Peru,
Nebraska
Problem on Coefficient of Linear Expansion of Steel
160. Theodore J. Kuemmerlein, (General Science) Boys' Technical High
School, Milwaukee, Wis.
Tests on Work & Motion.
161. Robert McCartney, Kingfisher, Okla.
Solution for 773.

162. Wm. Groff, Jr., Ephrata High School, Ephrata, Pa.
Solution for 773.
163. Chemistry Class of Berns Wm Cook, Omro High & Webster Manual
Training School, Omro, Wis.
164. Donovan Foote, Omro High School.
Solution for 773
165. Lucille Tenant, Omro High School.
Solution for 773
166. Seymour J. Sherman, 2078 Vyse Ave., New York City.
Solution for 773

TRADE PROBLEM NO. 3.—A PROBLEM IN MECHANICS

(In the December, 1936 issue of *SCHOOL SCIENCE AND MATHEMATICS* **Science Questions Dept.** proposed to **Mathematics Problems Dept.** an exchange of courtesies in publishing "border line" problems. Two such problems (nos. 772 & 773) were proposed. Numerous answers to 773 have been received and some solutions and acknowledgments are published in this number (February, 1937). Here is Trade No. 3.)

780. *Proposed by Clyde A. Bridger, Mackay, Idaho (Elected to GQRA, No. 157)*

Problems in Mechanics relating to loci of the instantaneous centers of some motion are always arising. Of particular interest to students of Auto Mechanics is the locus of the instantaneous centers of the motion of the piston and crank-pin of a reciprocating engine. The usual procedure to solve the problem is to prepare a graph and to select desired values from this graph, one graph being available only for each individual problem. As an applicant for membership to the GQRA, I am submitting the following question with a view to finding a simpler solution than the one I present:

Question: What is a general solution giving the locus of the instantaneous centers of the motion of the piston and crank-pin on the crank-shaft of any reciprocating engine?

(What is your Solution?)

WHETHER OUR SCIENCE COURSES ARE AFFECTING OUR STUDENTS IN PRACTICAL WAYS

781. *Tests—Proposed by Collis M. Bardin. Washington Union High School, Fresno, California (Elected to GQRA. No. 158)*

I enclose a set of questions for your GQRA in *SCHOOL SCIENCE AND MATHEMATICS* which may be of interest. This is the present form of a set which I have been slowly developing for some time and have used at the beginning and the end of the year in an attempt to learn "whether our science courses are affecting students in practical ways."

The selection of questions is neither complete nor well-balanced as yet. Nor are there any "conclusions" of great interest. I have, however, found the results interesting and helpful in improving our instruction. It should be noted, of course, that the emphasis in that instruction is on understanding of principles and that the specific applications used in the test are in no way emphasized because of their occurrence there.

I recognize the limitations of your space, and if I were to select a few of the questions as having been most interesting as to results, I would suggest:

8, 15, 16, 17, 19, 37, 68, 71, 73, 75, 76, 80, 83, 85, 89. Stars are placed opposite these numbers in the lists that follow.

Four points are noticeable to date; a) the unpredictably complete ignorance of some students of what are often assumed to be items of common knowledge, b) the occasional question which is more often answered correctly by poor students than by good students—this persisting sometimes in spite of revisions of form, c) the questions in which the sophistication of a little learning proves disastrous and more wrong answers are received after instruction than before, and d) the appreciable average gain in correct answers as a result of instruction.

Questions 1 to 80 follow.

Questions 81 to 187 will be published in March and April, 1937.

Mark T in left margin or correct by changing where *not* italicized. Avoid mere negatives. *Do not guess* as these papers will *not* be graded.

1. Violently boiling water is hotter than water boiling gently.
2. In freezing ice cream, the salt is used to make the ice melt.
3. In freezing ice cream, the proportion of salt should be within fairly definite limits.
4. In freezing ice cream, the freezer should be turned as rapidly as possible.
5. In freezing ice cream, the outside container is best made of metal.
6. After freezing ice cream, it should be packed with a mixture containing more salt.
7. Proper care for a storage battery includes; keeping cells filled with tap water, not overcharging, not charging too rapidly, not leaving discharged, protecting against too rapid discharge (avoiding shorts), adding acid when the battery is run down, adding glycerin when in danger of freezing, keeping terminals free from corrosion.
- 8.* A crowded room frequently becomes uncomfortable because of; poisonous substances given off by the people present, an excess of carbon dioxide turned into the room, a deficiency of oxygen in the air of the room, a rise of temperature, an increase of humidity, or lack of motion of the air.
9. The following should be kept in the coldest part of the refrigerator—directly under the ice or the freezing unit and at the bottom; raw meat, dairy products, salad dressings, creamed foods, smelly foods, fruit, vegetables.
10. A pressure cooker cooks faster and at a higher temperature than ordinary boiling.
11. At high elevations cooking times have to be decreased.
12. Dry ice is useful in a refrigerator.
13. Brass sockets should not be used on extension cords.
14. Tap water put into a thermos bottle would be cooler at the end of four hours on a hot day than if put into a porous jar or bag.
- 15.* Canned food may be warmed by direct heating of the unopened can.
- 16.* At high altitudes carburetors should be adjusted to mix more gasoline with the air.
- 17.* When the carburetor is kept properly adjusted the power developed by a car should be independent of altitude.
18. Electric bulbs should be chosen for long life.
- 19.* For economy, saucepans should have dull black bottoms.
20. In the northern hemisphere the compass needle points true north.

21. In the *southern hemisphere* the compass needle points south.
22. *Lightning flashes* do not occur where there is an efficient lightning rod.
23. *Electric clocks* run correctly only on D.C. of current voltage and amperage.
24. A *penny substituted* for a burned out fuse constitutes a fire hazard.
25. Christmas tree lamps which *all go out* when one lamp burns out are connected in series.
26. The tensile strength of the thread from which cloth is made is an important factor in the *quality of the cloth*.
27. In towing another car, the tow car must tighten a *slack tow-rope* slowly.
28. In using a hammer to *pull long nails*, the pull on a nail is increased at the end of the process if the hammer is raised on a block of wood.
29. To shift from *high to second* the motor should be speeded up while shifting.
30. An *octane selector* is just a spark lever.
31. A *ring around the moon* indicates the approach of a storm.
32. *Clear nights* are colder than cloudy ones.
33. *Thick fur* on animals foretells a cold winter.
34. *Hydraulic brakes* automatically secure even brake pressures.
35. On long grades, *brakes* may well be *saved* by turning off the ignition.
36. When made of the same kind of glass, thick glasses *break from heat shock* more frequently than thin ones.
- 37.* Glass with a lower index of refraction is *less subject* to breakage from *heat*.
38. Aluminum is preferable to enamelware for *serving hot drinks* while camping.
39. A *house* with an irrigated field on the windward side is *cooler* than one without.
40. Less *discomfort* accompanies high temperatures with 60% humidity than with 80%.
41. A burn from *steam* is less *serious* than one from similar contact with boiling water.
42. A sweater *under* a coat is *warmer* than vice versa.
43. A shiny tinned surface is better than a thin layer of asbestos as a *preventive of heat loss* from pipes carrying hot air for house heating.
44. Cork board is the best *insulator for refrigerators*.
45. The *coldest part* of the refrigerator is nearest to the top of the ice.
46. It is good practice to let one cake of ice *melt* in the refrigerator almost completely *before* replenishing.
47. The *temperatures* maintained by an ice box are *dependent* on the amount of surface of ice exposed.
48. Circulation in an *ice box* should be carefully maintained by keeping ice away from the sides of the ice-compartment *and* by not choking the passages by storing too much.
49. *Gilding radiators* is usually of little importance in *economy*.
50. Radio tubes in a set should all be *replaced* at once.
51. Radio tubes may be accurately *tested* while out of the set.
52. *Antenna leads* should be equipped with lightning arrestors.
53. Distribution of light without glare is at least of equal *importance* to proper intensity of light for *eye welfare*.
54. About ten foot-candles is needed for average *reading purposes*.
55. Converging lenses *correct near-sightedness*.
56. In replacing astigmatic eye-glass *lenses* care should be taken to place them at the *proper angle* in the frames.

57. A blue *spotlight* and a yellow spotlight turned on a white dress would make it *appear* green.
58. A *color-blind* person sees only black and white.
59. To *improve* the *sharpness* of a photograph as large an opening of the diaphragm should be used as light conditions will allow.
60. If a motor becomes *overheated* through shortage of water, the motor should be stopped while *filling* the radiator.
61. A *pressure cooker* should not be used unless safety valve and pressure gauge are both working properly.
62. *Wrapping* ice increases the efficiency of the refrigerator.
63. Refrigerators should be *insulated* with the equivalent of at least two inches of cork-board.
64. *Refrigerator doors* should be kept so that they close tightly.
65. *Contact* of a gas flame with metal surfaces improves combustion.
66. *Hypochlorites*, e.g., "*Clorox*," attack animal fibers.
67. The addition of salt to wash water improves the *fastness* of some dyes.
68. **Alcohol* in small amounts increases the speed of a person's reactions.
69. Canned foods which are found to be slightly *discolored* but which show *no other* signs of spoilage should be discarded as unsafe.
70. Acid foods should never be left in *enamelware* unless the glaze is known to be lead and antimony free.
71. **To meet* the standards of the U. S. Public Health Service raw milk to be *pasteurized* to grade A must be at least grade B raw.
72. *Canton* linen is not linen.
73. **In cooking* there is ordinarily no advantage in *rapid boiling* over slow boiling.
74. In order to *keep oily rags* without danger metal containers are necessary.
75. **Treatment* of the air with *ozone* is an efficient preventive of the spread of *disease* in crowds.
76. **When gas* burns so that there is no odor, it is producing a negligible amount of *carbon monoxide*.
77. Ammonia can be used in *higher* concentrations than lye without damage due to the *alkali* present.
78. Washing soda can be used in *higher* concentrations than trisodium phosphate without damage due to the *alkali* present.
79. *Corn* may safely be canned by the open kettle method.
80. **Cracked* gasolines are better than others.

What Happens to the Beam of Light

782. *Proposed by John C. Packard (GQRA No. 1.) Brookline High School, Brookline, Mass.*

"I have been waiting to get hold of a copy of last June's College Entrance Examination Board paper in Physics to ask you to call for solutions to the problem about the ray of light striking at right angles to a thick plate of glass (782) and the one about how to find the Sp. Gr. of a body by means of a dish of water and a graduated rule only (783). Highly suggestive problems and I may say provocative queries."

(Question 6, Part I—Answer all questions in this part)

A beam of white light is directed perpendicularly upon a slab of glass with parallel sides, 100 centimeters thick.

- a) If the light is suddenly flashed on, which color will emerge first, red or violet?

- b) What will be the distance between them when the red emerges? Choose the correct indexes of refraction for the two colors from the following numbers: 1.56, 3.75, 0.8, 1.53. Velocity of light = 300,000,000 meters per second in air.

FIND THE SPECIFIC GRAVITY

783. (Question 11, Part II—Select three questions out of 7 to 12.)

Given an empty can, a foot rule, and a large vessel of water, how might you proceed to find the specific gravity of a stone small enough to go in the can?

TRADE NO. 4.—EXPANSION CAUSES RISE OF MID-POINT

Submitted by Arthur L. Hill (GQRA, No. 115), Peru State Teachers College, Peru, Nebraska.

"One of the members of the students' Mathematics Club, Mr. Wolter, submitted this problem to me the other day and I suggested that he prepare it to meet the qualifications for membership in the GQRA, hence I am sending it on to you with the hope that it will be accepted.

I think, when we get started, all the active members of our Mathematics Club will be able to submit original problems."

784. Proposed by Frederick Wolter, student, Peru State Teachers College, (Elected to GQRA, No. 159)

To become eligible for membership to the GQRA I propose the following science problem.

If the coefficient of linear expansion of steel (1.2×10^{-6} C, from 0° – 100° C.) is taken as 10.5×10^{-6} and a steel bar has its ends fixed so that expansion takes place in the form of the arc of a circle find the distance the mid-point rises from the horizontal for a bar one mile long if the temperature increases one hundred degrees Centigrade.

GENERAL SCIENCE TESTS

785. Submitted by Theodore J. Kuemmerlein, Boys' Technical High School, Milwaukee, Wis. (Elected to GQRA, No. 160)

"Enclosed is a copy of one of my general science tests. This particular test is used in conjunction with Hunter and Whitmans' "Problems in General Science," the unit on Work and Motion 9A science. It seems to do a pretty good job of testing for facts, but I wonder how much understanding of principles, laws, etc., it measures. In other words does it measure other things besides facts?

I would appreciate your using this in your section of the journal and perhaps I might get some help from others."

BOYS' TECHNICAL HIGH SCHOOL, GENERAL SCIENCE 9A

Unit 12 Work and Motion Problem 1 Part 1 Test 4

Directions: Pick out the principle that best explains the situation and write the letter of that principle after the number of the situation.

- A. A body at rest tends to remain at rest.

- B. A body in motion tends to remain in motion.
 - C. It requires force to increase or decrease the speed of a moving body.
 - D. It requires force to change the direction of a moving body.
 - E. The greater the change in motion to be produced, the greater is the force required.
 - F. Friction may produce heat.
1. The train was moving very rapidly, as it slowed down the people swayed to the front of the train.
 2. A table cloth was jerked from under the dishes on the table without moving them forward.
 3. The street car was moving slowly. The motorman had to apply more power to make it move faster.
 4. A boy sliding down a rope may burn his hands.
 5. I was walking forward in a moving train and fell forward when the train suddenly stopped.
 6. As the train went around a curve I felt a sidewise pull on my body.
 7. People sometimes warm their hands in cold weather by rubbing them together.
 8. When the train started suddenly, I almost fell over backwards.
 9. Savages sometimes started fires by rubbing two sticks together.
 10. When the hammer handle was struck against the table the head was driven on tighter.
 11. One car was to be towed by another, the first car starts with a sudden jerk. The tow line breaks.
 12. A coin is placed on a card over a glass. The card is snapped quickly, the coin drops into the glass.
 13. The driver's leg became tired from pushing the brake on the long hill.
 14. The flywheel of an engine keeps on moving after the power is turned off.

BOYS' TECHNICAL HIGH SCHOOL, GENERAL SCIENCE 9A*Unit 12 Work and Motion**Part 2 Test 4*

Modified true and false.

Directions: Write the word TRUE or FALSE after the number of the statement. Then if the statement is false correct the underlined words only, so that the statement will be a true one.

1. Work is the overcoming of resistance through time.
2. The attraction of everything for every other thing is called magnetism.
3. A body has weight because inertia acts upon it.
4. If there was no gravity a bullet when shot into the air would continue to travel forever.
5. A body in motion will continue in motion until friction stops it. This is called inertia of rest.
6. A body has inertia when it is in motion and when it is at rest.
7. A machine can create energy.
8. Work is done whenever a push or a pull is exerted upon a body.
9. Force is the result of doing work.
10. Power in an automobile is a term used to express the ability of the engine to overcome resistance.

BOYS' TECHNICAL HIGH SCHOOL, SCIENCE DEPARTMENT 9A*Unit 12 Work and Motion**Part 3 Test 4*

1. Match the units in column A with the comparable ones in column B.

<i>A</i>	<i>B</i>
meter	inch
centimeter	ounce
mile	yard
gram	kilogram
pound	gram
cubic centimeter of	kilometer
water at 4°C.	quart
	liter

(Note in questions 2, 4, 5, 6, 7, mark all of the answers correct or incorrect.)

2. The metric system is used in science because:
 - a. it is French.
 - b. it is easier to work with than the English system.
 - c. it is new.
 - d. it is scientific
 - e. it is international.
3. In which of the following cases is friction a help or a hinderance? Indicate after the number of the case—HELP or HINDER.
 - a. bearings of a wheel.
 - b. a wedge.
 - c. tread of a tire and the road.
 - d. the brake bands on an auto.
 - e. an eraser and the paper.
 - f. a match and a match scratcher.
 - g. an airplane flying through the air.
 - h. a cork on a bottle (remember the purpose of a cork).
 - i. a nail.
4. A hunter firing a shotgun receives a "kick" or jar from the gun because:
 - a. of the friction of the bullet in the gun.
 - b. the inertia of rest of the bullet must be overcome very quickly which requires a great force.
 - c. the expanding force of the powder must push against something to move the bullet.
 - d. the burned powder cannot escape.
 - e. the hunter does not hold the gun properly.
5. A ten horse power engine is capable of doing:
 - a. ten times as much work as one horse.
 - b. 330,000 foot pounds of work every minute.
 - c. 33,000 foot pounds of work every minute.
 - d. (lifting) 330,000 pounds one foot in one minute.
 - e. work more efficiently than a horse.
6. A river can be the source of hydro-electric power because:
 - a. water flows down hill.
 - b. the water was put in a position to do work by the sun.
 - c. water in falling from a higher level to a lower level has the capacity to turn turbine wheels.
 - d. it may have a large supply of water available at one time and little at other times.
 - e. we can get the necessary water for the steam boilers.
7. If you weigh 150 pounds that means that:
 - a. that the scale pulls on you with that force.
 - b. the earth pulls on you to that extent.
 - c. the spring of the scale gives that much.

- d. the moon exerts a pull of gravity of that much on you.
e. you have a mass of more than 150 pounds.

COLOR OF HOT AND COLD SALT SOLUTIONS

786. *Proposed by Leo R. Spogen (GQRA, No. 64), Red Lodge, Montana.*

"I have a question of your question department—Why is a cold saturated solution of sodium chloride clear and a hot saturated solution of sodium chloride yellow?"

SOLUTIONS TO TRADE NO. 2.

773. *Proposed by James C. King, a boy in Central District Catholic High School, Pittsburgh, Pa. (Elected to GQRA, No. 154) and sent in by Brother Felix John (GQRA, No. 17).*

A "guy" had a thousand dollars and ten bags. How shall he distribute the money in the ten bags so that he can give out any amount in dollars from one to a thousand without having to take any money out of any of the bags?

Solutions from Chemistry Class of Berns Wm Cook, Omro High and Webster Manual Training School (Elected to GQRA, No. 163), Omro, Wisconsin.

In my Chemistry class we worked the problem 773 on page 1033 of the December 1936 issue of the SCHOOL SCIENCE AND MATHEMATICS Magazine.

Two plans were submitted by Donovan Foote (*Elected to GQRA, No. 164*) and Lucille Tenant (*Elected to GQRA, No. 165*)

Donovan Foote

Bag 1— 1
Bag 2— 2
Bag 3— 4
Bag 4— 8
Bag 5— 16
Bag 6— 32
Bag 7— 64
Bag 8—128
Bag 9—256
Bag 10—489

Lucille Tenant

Bag 1— 1
Bag 2— 2
Bag 3— 4
Bag 4— 8
Bag 5— 16
Bag 6— 32
Bag 7— 63
Bag 8—126
Bag 9—252
Bag 10—496

Both of these solutions proved to be correct.

Solution by Robert McCartney, Kingfisher, Oklahoma.

"I hope this answer will let me in your GQRA" (*Elected to the GQRA, No. 161*).

Answers the same as Donovan Foote.

Solution by Seymour J. Sherman, 2078 Vyse Ave., New York, N. Y. (Elected to GQRA, No. 166.)

One solution of the problem is

1, 2, 4, 8, 16, 32, 64, 128, 256, 489.

Every bag except the tenth contains twice as much as the one immediately preceding. It is evident that at any point we can construct any sum up to one less than twice the number at the point selected. The amounts in

the 6th, 7th, 8th, 9th, and 10th bags may be varied; the others may not. The bags may take values as follows:

6th— 32, 31
 7th— 64, 63
 8th—128, 127, 126, 125
 9th—256, 255, 254, 253, 252, 251, 250.

The values in the 10th bag are increased from 489 to make up the amount necessary to equal \$1,000.

*Solution by William Groff Jr. Ephrata High School, Ephrata, Pa.
 (Elected to GQRA, No. 162.)*

"He puts 1, 2, 4, 8, 16, 32, 64, 128, 256 and 489 dollars in the ten bags respectively. Thank you!!"

JOIN THE GQRA

BOOK REVIEWS

A Textbook of Trigonometry for Colleges and Engineering Schools, by William H. H. Cowles and James E. Thompson, Department of Mathematics, School of Science and Technology, Pratt Institute. Cloth. Pages x+373. 15×23 cm. 1936. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York, N. Y. Price \$2.50.

This book is designed to meet the needs of students who stand at various levels of preparation and who plan to enter fields which require a good mathematical foundation. There is an abundance of topics and problems from which an instructor may select material to suit the needs of any class.

There are many features which deserve mention. The first chapter devotes 23 pages to the discussion of angles, angle measure, rotation, and angular velocity. The trigonometric functions are defined for the general angle, thus eliminating some lost motion. In the third and fourth chapters, the student is given an opportunity to use the slide rule to find the values of the trigonometric functions and to solve the right triangle. In the fifth chapter we find a discussion of accuracy, precision, and significant figures. There is a good discussion of angle measurement and surveying measurement. Several pages are devoted to projections, forces, vectors, and components. The eighth chapter deals with the inverse functions. The eleventh chapter is devoted to applications of trigonometry to the parallelogram of forces and vector sum, to properties of parallelograms, problems in plane surveying, and problems of geodesy and astronomy. In the twelfth chapter we find a treatment of polar coordinates including polar graphs, complex numbers, and De Moivre's Theorem. The thirteenth chapter is devoted to series expansion and related topics. We find the expansion of $\csc n\theta$, series expansions of sine and cosine of multiple angles, series expansions of the trigonometric functions and their inverses, computation of π , exponential form of complex numbers, logarithms of complex numbers, and logarithms of negative real numbers.

Much attention is given to the graphical study of the functions. There is an enormous amount of problem material both theoretical and applied. It is the opinion of the reviewer that this book deserves the attention of all teachers of college trigonometry.

J. M. KINNEY

An Introduction to Mathematical Analysis, Revised Edition, by Frank Loxley Griffin, Professor of Mathematics, Reed College, Portland Ore-

gon. Cloth. Pages x+546. 14×20 cm. Houghton Mifflin Company, 2 Park Street, Boston. 1936. Price \$2.75.

This is a revision of a book of the same title that appeared in 1921 and which has been used extensively. The book furnishes material for one year of college freshman mathematics. This material has been skillfully organized by making the function concept the organizing principle. In this book we find the material of the standard courses—college algebra, trigonometry, and analytic geometry—brought together and woven into a unified whole.

Algebra and trigonometry are manifestations of different types of functions. The functions are studied from the standpoint of variation, rate of change, and anti-rate of change. Analytic geometry is also treated from the functional standpoint. Here the curve determines a functional equation. After the equation of the curve has been discovered the properties of the curve may be determined from the properties of the function defined by the equation.

The book is divided into fifteen chapters as follows: I. Functions and Graphs. In this chapter we find a study of the problem of variation, the rate problem, the mean-value problem, the extreme value problem, and the zero-value problem. II. As to Exact Relationships. III. Differentiation. IV. Integration. V. Trigonometric Functions. VI. Logarithms. VII. Exponential and Logarithmic Functions. VIII. Rectangular Coordinates. IX. Solution of Equations. X. Polar Coordinates and Trigonometric Functions. XI. Trigonometric Analysis. XII. Definite Integrals. XIII.

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J. M. KINNEY

Plane and Spherical Trigonometry with Applications, by J. Shibli, the Pennsylvania State College. New Edition. Cloth. Pages xii + 242 + 94. 15 × 21 cm. Ginn and Company, 15 Ashburton Place, Boston, Mass. Price \$1.96.

This book is designed for students of some maturity. The first chapter on "The Object of Trigonometry" discusses the problem of direct and indirect measurement, mentions the uses of trigonometry, and gives some facts concerning the development of the subject. The second and third chapters define and use the functions of the acute angle. Chapters IV and V introduce logarithms and use them in the solution of the right triangle. In Chapter VI the functions of the general angle are introduced and in Chapter VII the variations of the functions are studied. Chapters VIII, IX, X, XI, XII are devoted to fundamental relations, oblique triangles, functions of two angles, functions of half angles, and complex numbers, respectively. Spherical Trigonometry is treated in Chapters XIII and IV.

There is an abundance of problems designed to take care of the individual differences of students. There are nine excellent tables of four four-place and five-place tables of trigonometric and logarithmic functions.

J. M. KINNEY

Science, by Ira C. Davis, Head of Department of Science, University High School, Assistant in the Teaching of Science, School of Education, University of Wisconsin, and Richard W. Sharpe, formerly Professor of Biology, State Normal School, River Falls, Wisconsin, and Instructor in Science, George Washington High School, New York City. Cloth. Pages xi + 491. 15 × 23.5 cm. 1936. Henry Holt and Company, 257 Fourth Ave., New York, N. Y. Price \$1.72.

This is more than a new ninth grade text in Science; it is really a new type of text with a number of distinctive features which are likely to be received with favor.

There are twenty units of well chosen work. Each Chapter presents (1) The Story of Progress and Discovery; (2) Questions to Direct the Study of this Chapter; (3) The Subject Matter; (4) Questions for Review and Discussion; (5) Test the Value of this Chapter; and (6) The Old and the New. One is impressed with three special features in the treatment of the subject; Science is presented as an essential factor in progress—the new has grown out of the old—science is a succession of human problems; every major idea is presented as a declarative statement—the objective of thought is positive and definite; a commendable effort is made to develop a scientific attitude toward life and its problems.

The book is well made and fully illustrated. The cover and title are simple and attractive; the large format has certain mechanical advantages—the main body of the text is in double columns for easy eye-span—illustrations are made more effective both in size and position; the many line drawings are exceptionally good—carefully labeled, clear, and instructive in character; suggestive and well designed illustrations emphasize human progress; the type is readable and varied.

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The square root of minus one, with symbol i , is not a number of the first dimension of algebra. The multiples of i , that is, $i1$, $i2$, $i3$ and their intervening fractions $i\frac{1}{2}$, $i\frac{1}{3}$, $i\frac{1}{4}$ and their opposites, $-i1$, $-i2$, $-i\frac{1}{2}$ constitute another dimension, the imaginary dimension of algebra.

Is this imaginary dimension the second dimension of algebra? No, logically, the imaginary numbers constitute the third, not the second, dimension of algebra.

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The FIRST dimension of algebra is formed of the multiples and fractions of unity. This is the UNITARY dimension.

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The THIRD dimension of algebra is formed of the multiples and fractions of the square root of negative unity. This is the IMAGINARY dimension.

This thesis is developed by Robert A. Philip in a monograph BIFOLIATE NUMBERS, Price one dollar, THE MONOGRAPHIC PRESS, 106 Washington St., Fairhaven, Mass.

Wherever possible the subject is developed from simple demonstrations. Individual exercises are provided in a separate manual. The subject matter has been carefully organized and simplified. Nevertheless the text probably contains more material than even our better students can master in a year. Teachers who examine this text will want to use it.

W. F. ROECKER

The Teaching of Mathematics, by Raleigh Schorling, Head of the Department of Mathematics in the University High School, University of Michigan. Pages viii + 247. 15 × 23 cm. 1936. The Ann Arbor Press, Ann Arbor, Michigan.

The sub-title "A Source Book and Guide" is a better explanation of the contents. The volume includes reprints of a few of the leading articles of the past decades such as Moore's presidential address and Smith's essay on "Mathematics for the Training of Citizenship." It also summarizes reports, suggestions, and results of various researches. There is a brief discussion of some of the troublesome and debatable points in teaching, of objectives, and of the use of historical material and recreations. The teacher who has not had opportunity to keep abreast with the latest theories and researches will find in this volume a splendid means of getting in step with the times.

JOSEPH A. NYBERG

Progressive Solid Geometry, by Walter W. Hart, Associate Professor of Mathematics, School of Education and Teacher of Mathematics, Wisconsin High School, University of Wisconsin. Cloth. Pages ix + 263, 1936. D. C. Heath and Company. Boston, New York, Chicago, Atlanta, San Francisco, Dallas and London.

This book is not merely a revision, but it has been written anew in order to keep abreast with modern ideas in the teaching of Solid Geometry. However, the tested and approved qualities of former texts have been retained and refined.

Throughout the book, the Author has kept in mind the varying needs and abilities of the students by providing a minimum course, many exercises of graded difficulties, and accompanying optional topics. The minimum course includes all the fundamental and other theorems necessary to build a logical sequence. The optional topics will challenge the imagination and abilities of the more capable individuals.

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HYMEN D. SILVERMAN

Second Courses in Algebra, by C. Newton Stokes, Teachers College, Temple University, Philadelphia, Pennsylvania and Vera Sanford, State Normal School, Oneonta, New York. 1936. Cloth. Pages v+388. Henry Holt and Company. New York.

The purpose of this book as stated in the authors' preface is, "To show how the subject-matter of mathematics, as it is related to a second course in Algebra, aids in the study of important phenomena, interpreting, explaining, and, in some instances, showing relationships which are not evident at first sight." The extent to which the authors carry out this purpose is evident by the organization, the presentation, and the quality of the subject-matter throughout the book.

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6. Illustrative materials showing the many and varied uses of algebra.
7. An appendix providing many additional problems and exercises.
8. A Chapter on important applications of algebra.

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HYMAN D. SILVERMAN

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